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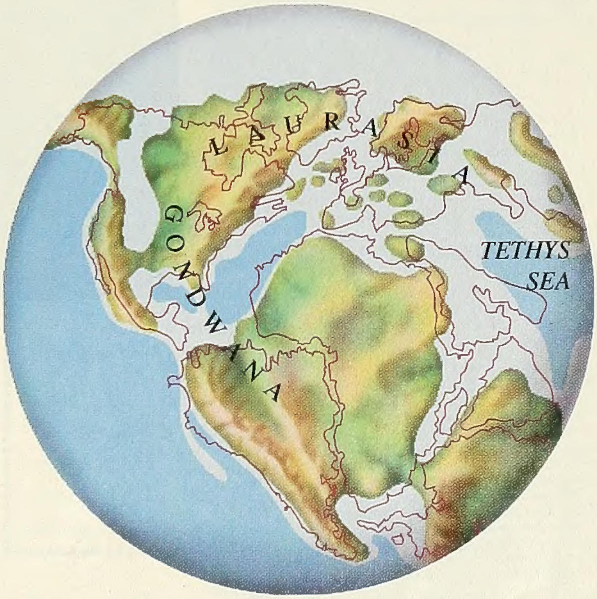

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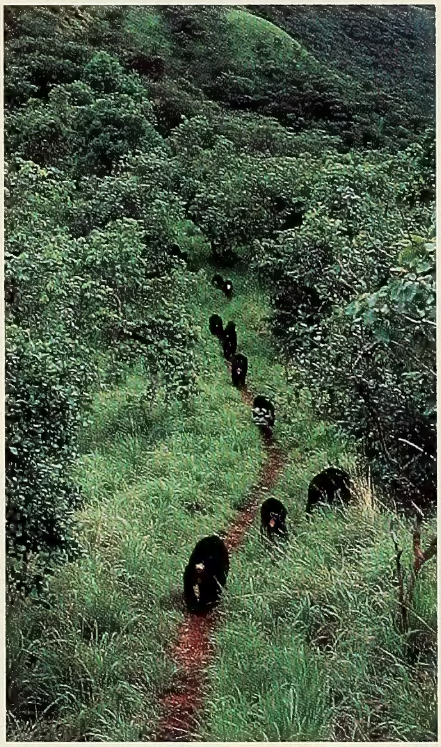

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LETTERS

Africa Maligned

While reviewing Craig Packer's book *Into Africa* (September 1994), Lory Frame takes the opportunity to express her own attitude toward what she calls "unhealthful, inconvenient, frustrating Africa." With reference to corrupt bureaucrats and politicians, Marxist rebels, shortages of toilet paper, and so on, she builds up an image of Africa that reinforces the advice George Schaller once gave her—"go in, get your data, and get out."

Firstly, Frame extrapolates her experiences in East Africa to the whole of Africa, which is misleading, since there are large parts of the continent, especially in southern Africa, that are peaceful and have excellent infrastructures. The Kruger Park in South Africa has research facilities that are the envy of ecologists working in Yellowstone and Denali. Zimbabwean parks like Hwange have always hosted foreign scientists, and the wardens and rangers here go out of their way (often too far, I think) to be helpful.

Secondly, the smash-and-grab approach to collecting data is exactly the reason that some foreign scientists experience problems when attempting to get research projects established in Africa. This is not surprising. Imagine how the U. S. Fish and Wildlife Service would respond to a steady stream of African ecologists insisting that they be allowed to set up camp in flagship national parks so that they could study charismatic species such as wolves, mountain lions, and polar bears. Add to this the suspicion that if research permits are granted, the scientists will disappear with the data.

Fieldwork in Africa certainly can be difficult and frustrations are inevitable, but this should not prevent foreign scientists from (a) making meaningful contributions toward improving the understanding and management of African biodiversity and (b) establishing good working relations with government wildlife agencies. Foreign scientists assist local students and scientists in developing their own research capacities. By sharing in the collection and analysis of data and stimulating local scientists to work on xenophobic officials, foreign scientists can make life in Africa much more pleasant for themselves and those that follow them.

Johan T. du Toit
Harare, Zimbabwe

Rock of Ages

In "Desert Snails' Daily Grind" (August 1994) Clive G. Jones and Moshe Shachak describe the bizarre rock-eating habits of the Negev's *Euchondrus* snails. While reading about these stone-eating snails of modern Israel, I was reminded of the legendary stone-eating *shamir* of ancient Israel.

Shamir (Hebrew for "sharp stone," or corundum) was the appellation given to a worm or snail that according to Jewish lore was used to hew stone for the construction of Solomon's Temple in ancient Israel. The *shamir* was essential for the building of the temple because tradition forbade the use of iron implements, symbolic of tools of war, in the construction of the Temple—the house of G-d and Peace. Thus, according to legend the ancient Israelites laid aside their iron tools and resorted to employing the *shamir* to hew the stones for the Temple.

One of the more salient features of *Euchondrus* is its radula: the tonguelike organ it uses to scrape the lichen-filled rock it then eats. Remarkably, the radula does not "appear to contain iron or other metals," making it an especially apt candidate for the legendary *shamir*.

Phillip Katz, Esq.
Brooklyn, New York

There still seems to be a gap in our knowledge about the snails of the Negev.

According to your article they turn "about 800 pounds of rock into soil per acre" per year, and 5 percent of the dry weight of their feces is nitrogen. If all they are doing to the rock is pulverizing it in the course of eating lichens, it is mostly going to pass out as feces—800 pounds per acre, which at 5 percent nitrogen would come to about 40 pounds. But the authors calculate a transfer of "three pounds of nitrogen to each acre . . . each year." I can't tell if the discrepancy is caused by missing information or bad arithmetic, so please fertilize our intellectual desert with an explanation.

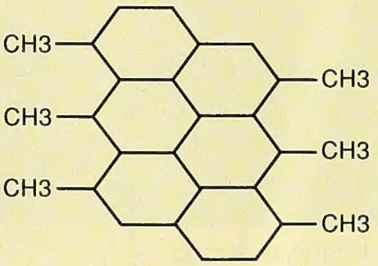
Donald Forman
Berkeley, California

The value for nitrogen in snail feces should read 0.5 percent. In removing zeros before decimal points, we inadvertently deleted the decimal point. Snails turn between 600 and 1,000 (average 800) pounds of rock per acre per year into soil, transferring a minimum of three pounds of nitrogen per acre per year. —*Eds.*

Comical Compounds

Just received your November issue and Roger Welsch's column ("Stand-up Chemist") brought back some memories that I've had stashed away in a folder in my desk for a long time. About 1974 a friend introduced me to an "organic chemistry quiz" that included some of the substances your contributor enclosed, plus a few others. Here are a couple that you didn't reproduce.

Lawrence Simon
Westlake, Ohio



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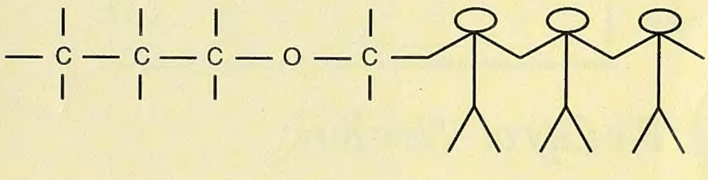

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LOST CIVILIZATIONS

Of Tongue Worms, Velvet Worms, and Water Bears

Fresh evidence confirms the uniqueness of the Cambrian explosion

by Stephen Jay Gould

I belong to a generation of students formally educated, in large measure, by the practice of rote memorization. Hence, I know the Gettysburg Address by heart (and who can ever expunge the arcana learned at age ten, while who, at age fifty, can retain the important items encountered last week). At least I know Lincoln's line for paleontologists: "... we here highly resolve that these dead shall not have died in vain." And, when Stephen Dedalus, in Joyce's novels, routes "on old Olympus's topmost tops" into his stream of consciousness, I know that he is musing upon the standard mnemonic for remembering the names of cranial nerves in proper sequence front to back—olfactory, optic, oculomoter. . . .

Among the classical items of rote memorization in early schooling, two stand out for later utility to paleontologists like me—the geological time scale and the list of animal phyla, the major taxonomic divisions of life in our kingdom (some twenty to forty depending on the version you learned). Most of my fellow students didn't complain too much about the dozen or so major groups, for everyone should know a vertebrate from an arthropod from a mollusk from an echinoderm, if only because we do encounter such creatures in our daily lives. But for the larger number of so-called minor phyla—the unrememberable whatchamacallits with such funny names as Ctenophora (comb jellies) and Priapulida (little penis worms)—most of us had only contempt and loathing, for we couldn't recall them on exams, and we never encountered them in Central Park or at Jones Beach ("nature" to New York City kids).

Yet these "minor" phyla embody some of the most fascinating problems of natural history and should not be ranked with the unknown and the unloved. They are, first of all, minor only in the sense of current membership (few species alive today); although some, brachiopods and bryozoans in particular, dominated the early fossil record of multicellular animal life. Moreover, these groups are decidedly not minor in degree of anatomical distinctness, for they are as different, one from the next, as a fish from a fly or a clam from a sea cucumber.

The minor phyla must play a crucial role in unraveling the greatest of all mysteries surrounding the history and fossil record of animal life. I have often written in these essays about the "Cambrian explosion," the extremely restricted time that encompasses the first appearance in the fossil record of nearly all basic anatomical designs for animal life. According to a recent study, the first ever based upon rigorously determined radiometric age dates, this episode lasted an astonishingly short 5 million years, from about 535 to 530 million years ago.

Since then, only one new phylum with a prominent fossil record has been added to life's archives—the Bryozoa, a group of small colonial organisms, which, like reef-building corals, secrete calcified skeletons surrounding the individual animals of a colony. (The bryozoans arose at the beginning of the very next, or Ordovician, period and their Cambrian absence may be an artifact of our failure to find earlier representatives.) One might argue without great exaggeration that 530 million years of subsequent evolution has produced no more than a set of variations upon themes established during this initial explosion—although some of these little fillips, including human consciousness and insect flight, have had quite an impact upon the history of life!

The minor phyla provide a key to the Cambrian explosion because they represent a potential exception and softening. This episode is enormously puzzling and contrary to preferred assumptions about the generally slow and steady character of evolutionary change. Therefore, paleontologists have sought (largely unconsciously, for thus do we act upon our deepest biases) mitigating circumstances or arguments that might either diminish or spread out the Cambrian explosion.

Among such sops to our uniformitarian preferences, none has been more common—I can hear the words in my mind as stated by a bevy of professors and read in dozens of books—than the following potential invocation of minor phyla to make the Cambrian explosion merely an intensification of ordinary possibilities, rather than an exclusivity: "But how can you claim that all phyla originated during this tiny beginning interval? After all, about half the animal phyla contain no hard parts at all and therefore have no fossil record. How do you know that these groups haven't been arising throughout the 530 million years since the Cambrian explosion? Moreover, most of these phyla contain very few species. Doesn't their rarity indicate a potentially recent origin, leaving little time for their gradual spread and speciation?"

This argument is not unreasonable and seems particularly strong under certain

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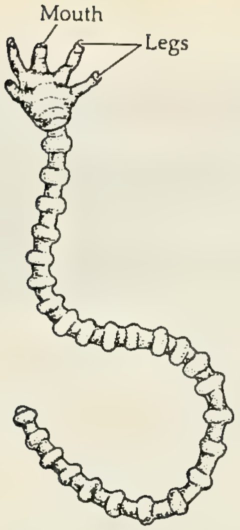
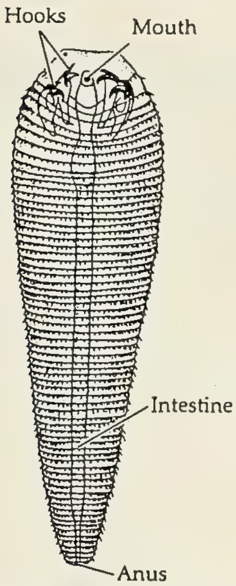


The pentastome Cephalobaena tetrapoda, *a tongue worm*
Nancy J. Haver, after Barth and Brosheârs, 1982. From *Invertebrates*, by Richard C. and Gary J. Brusca, Sinauer Associates, 1990. With permission.

circumstances. Consider, for example, the case of a classic minor phylum of small membership—the Pentastomida, or tongue worms. (Their name literally means five-mouthed, in reference to the two pairs of limbs surrounding the true mouth at the anterior end. In some species the mouth resides at the end of a stalk comparable in length to the surrounding four legs, thus giving the appearance of a five-pointed star. The usual name of "tongue worm" commemorates the more common species that resemble a vertebrate tongue in miniature.)



The pentastome Linguatula serrata
Nancy J. Haver, after Sedgewick, 1888. From *Invertebrates*, Brusca and Brusca, 1990

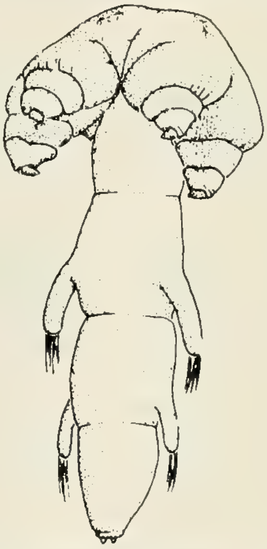
Pentastomes are parasites, and they live almost exclusively upon terrestrial vertebrates—a group that did not evolve until well after the Cambrian explosion. Pentastomes also resemble crustacean arthropods in a few important features. Therefore, following a century of intense debate and a range of hypotheses that either allied pentastomes with other major phyla or gave them separate status on their own, a recent consensus had emerged for viewing these intensely enigmatic creatures as a phylum evolved from a crustacean stock much later than the Cambrian explosion. And if the unique pentastomes could evolve more recently from a well-established group, why not most of the other minor phyla as well? The Cambrian explosion would then lose its exclusivity, and the "phylum-making machine" of evolution would continue to operate throughout geological time.

I write this essay to present some freshly published data leading to the opposite point of view—that the Cambrian explosion is even more extensive in scope and exclusive in effect than heretofore recognized even by its partisans. These data have been presented in two papers, published in 1994 by my German paleontological colleagues Dieter Walossek and Klaus J. Müller, of the Rheinische Friedrich-Wilhelms Universität in Bonn. Such long and technical articles on the anatomy of small Cambrian fossils invariably fall by the wayside in public perception (while often creating a quite a buzz in the tiny circle of paleontological professionals). Very few "science writers" from the journalistic side have much patience with the arcana of descriptive anatomy (and professional traditions of jargonized presentation contribute to the impasse as well). Moreover, and more sadly, taxonomy and anatomy occupy the lowest rung in the ladder of scientific status—an old-fashioned, albeit harmless and gentle, pursuit more suited to the eighteenth-century days of Linnaeus than to the modern world of molecular biology.

Yet the importance of a discovery lies in the impact and reforming power of ideas expressed and theories thereby altered, not in the "modernity" of methodology employed. Thoughtless adherence to fashion can blind us to the permanent value of things unnoticed or abandoned as outdated. Just think of such luminous and enduring figures as Bach and Brahms, dismissed in their maturity as hopelessly antediluvian by a gaggle of forgotten devotees to the "latest" trends. Judge by quality and engagement with the central ideas of a science, not by employment of the maximally fashionable machinery or jargon.

Arthropods constitute the largest phylum by far, with major subgroups of insects, chelicerates (spiders, mites, scorpions, and horseshoe crabs), and crustaceans (crabs, shrimp, lobsters, and many other marine forms). Three minor phyla—the Onychophora, or velvet worms; the Tardigrada, or water bears; and the Pentastomida, or tongue worms—are conventionally placed near the arthropods because they possess a few key anatomical features that suggest possible genealogical proximity to this greatest of all groups. For example, the most popular recent textbook of invertebrate biology (*Invertebrates*, by Richard C. and Gary J. Brusca, Sinauer Associates, 1990) grants them an entire chapter, under the heading: "Three Enigmatic Groups and a Review of Arthropod Phylogeny."

These three phyla provide an excellent case for testing the hypothesis that phyla continue to originate throughout time, and that the Cambrian explosion is not so exclusive as the fossil record, read literally, might suggest—for they are usually discussed together and share all key features for putative origin in later geological time (small modern membership and absence of hard parts, leaving little opportunity for preservation of fossils); moreover, one of the three, the Pentastomida, has been widely interpreted as an offshoot of the crustacean line.



The newly discovered Heymoniscambria scandica, *a fossil pentastome larva from the Upper Cambrian in Sweden*
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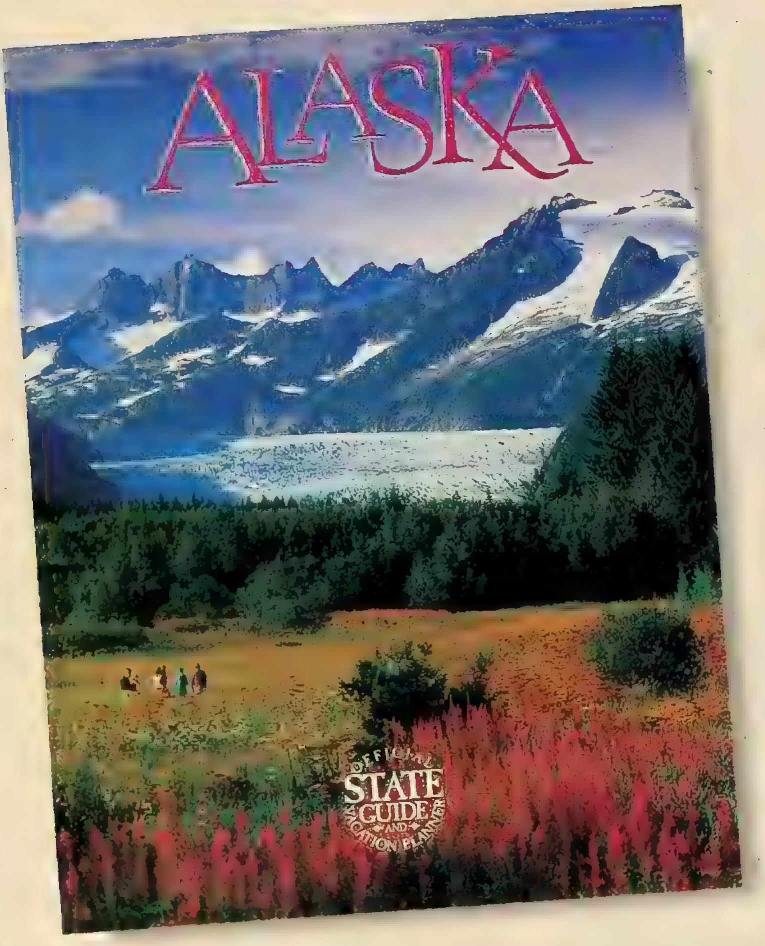
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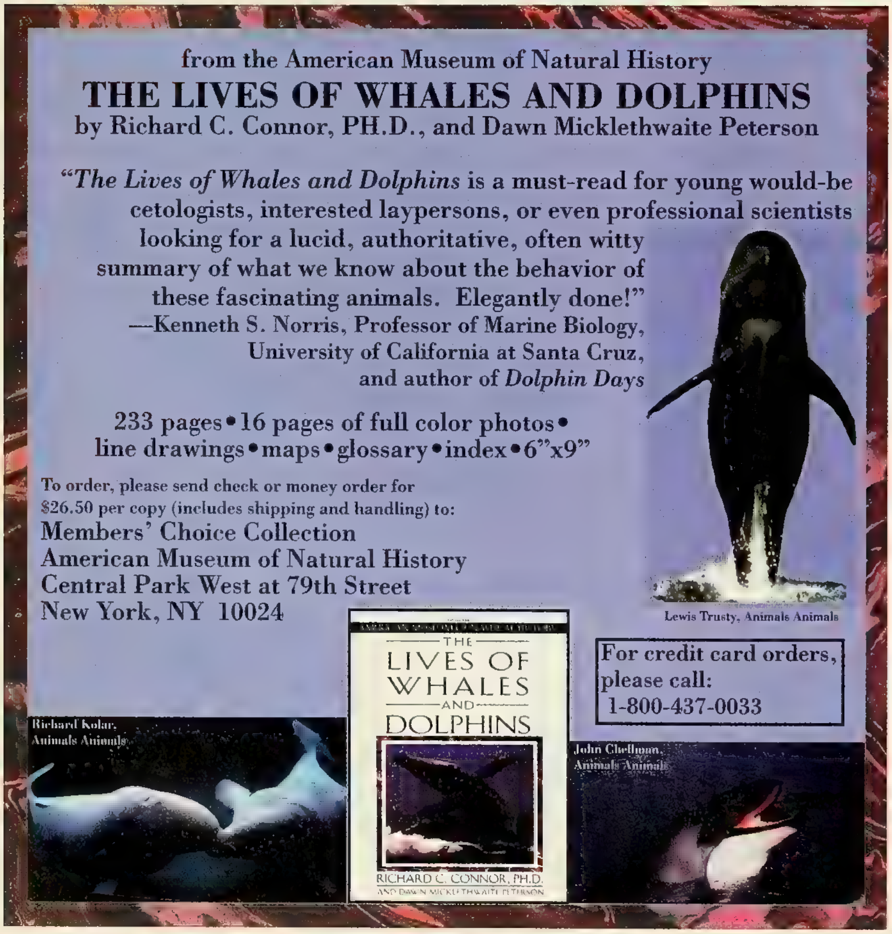
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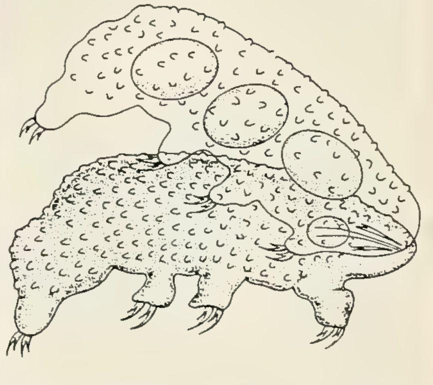
THE LIVES OF WHALES AND DOLPHINS
RICHARD C. CONNOR, PH.D.
AND DAWN MICKLETHWAITE PETERSON

that the Onychophora have a fossil record extending right back to the Cambrian explosion. Modern velvet worms live in moist, terrestrial habitats, usually in wet leaves or rotting wood. Most of the eighty or so species are one to three inches in length and have an elongated body with fourteen to forty-three pairs of stumpy legs (called lobopods) behind a head bearing three pairs of appendages (antennae, jaws, and slime papillae, used by these carnivores to shoot a sticky substance at prey). The entire animal looks vaguely like a caterpillar, although onychophorans have no close genealogical relationship with these larvae of moths and butterflies.

Cambrian onychophorans have been proposed for eighty years, since the discovery of *Aysheaia*, a soft-bodied fossil from the famous Burgess Shale in British Columbia. But *Aysheaia* had remained in limbo, with many paleontologists doubting its proper inclusion among the velvet worms, until the discovery of at least four more Cambrian genera during the past ten years, including a reinterpretation of *Hallucigenia*, once the most enigmatic of all Burgess Shale creatures, as an onychophoran originally misconstrued as upside down. These exciting finds show that velvet worms are only minor in current membership and restricted ecological spread. The Onychophora began as a diverse and important group of Cambrian marine invertebrates.

Walossek and Müller have now discovered Cambrian fossils of tardigrades and pentastomes as well, so we can now affirm that all three phyla go right back to the initial diversification of multicellular animal life in the Cambrian explosion. Until these exciting publications, neither tardigrades nor pentastomes had a recognized fossil record at all—not a single specimen from any time. So these new discoveries from



A female tardigrade, or water bear, molts her egg-filled cuticle.
Nancy J. Haver, after Morgan, 1982. From *Invertebrates*, Brusca and Brusca, 1990

the dawn of phyla allow both groups to leapfrog from the present right back to the beginning.

Living tardigrades are tiny creatures, usually only one-tenth to one-half millimeter in length (hardly visible since one inch contains 25.4 millimeters), although the "giant" of the phylum reaches 1.7 millimeters. Most of the 400 species live in water films on mosses, lichens, flowering plants, soil, or forest litter, although some inhabit freshwater or marine environments on the sediment surfaces of ponds or ocean basins. They look like tiny eight-legged bears, and they move with a lumbering gait—hence their common designation of "water bear," although the etymology of their technical name also invokes form and motion, for tardigrade means slow-stepper.

Tardigrades have attained a certain notoriety in popular science writing for a suite of unusual features—not to mention their charmingly humorous appearance. Some species indulge in an odd form of reproduction by indirect fertilization. Males penetrate the female's cuticle and deposit sperm beneath. The female then sheds her cuticle (for tardigrades, like insects, grow by molting an external covering and secreting a new and larger version), and lays eggs into this discarded outer shell, already well supplied with previously deposited sperm.

But tardigrades are most famous for their astonishing capacity to shut off metabolism and endure long periods of dormancy—a condition known as cryptobiosis and defined as a state of dormancy so extreme that no external sign of metabolic activity can be detected at all.

If their habitat dries up (and life in terrestrial water films can be precarious), tardigrades can pull in their legs and secrete a cuticle about their withered body. In this so-called tun stage, tardigrades can survive extreme insults perpetrated by nature or invented by human experimenters—such as immersion in absolute alcohol, ether, or liquid helium and exposure to temperatures ranging from 149° C (well above the boiling point of water) to –272° C (not so far from absolute zero)! When water becomes available again, the animal swells up and returns to activity within a few hours. No one knows how long a tardigrade tun might survive. The Bruscas' text recounts one tale (likely apocryphal) of living tardigrades emerging from a museum specimen of moss that had been moistened after 120 years of dry shelf life. Unsurprisingly, tardigrades have

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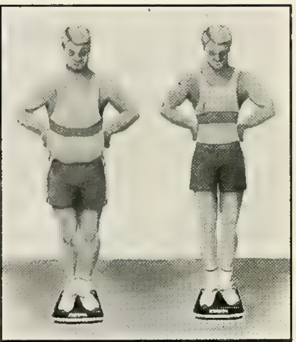

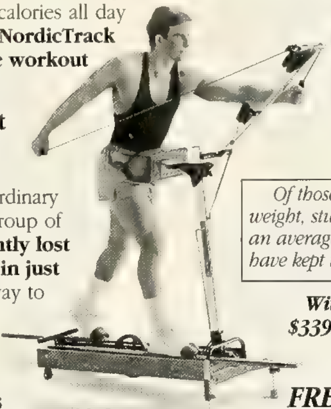

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been of special experimental interest to students of aging.

The Sixth International Symposium on Tardigrada met in Cambridge, England, August 22 to 26, 1994 (my heart warms to the thought that even minor phyla can spawn such multiple and cosmopolitan celebrations by their human devotees). At this meeting, Walossek, Müller, and R. M. Kristensen, of the Zoological Museum of the University of Copenhagen, presented a show-stopping paper entitled "A More Than Half a Billion Years Old Stem-Group Tardigrade from Siberia." They had found the first indisputable tardigrade fossil, and this species dated right back to the verge of the Cambrian explosion.

These specimens look just like tardigrades and range from 0.25 to 0.35 millimeters in length (a middling size for modern tardigrades). But the key to identification lies not in similar sizes or general appearances, for such basic features can be evolved by convergence in independent lineages, but in a large and striking set of unique and complex traits found only in these fossils and in living tardigrades. These marks of genealogical affinity include a distinctive pitlike mouth, limbs with paired hooks, or claws, that can be withdrawn at their outer edges, and minute plate-shaped knobs between the limbs.

The pentastomes provided a much better potential case—the classic instance among minor phyla, one might even have said—for continuing origin of major groups after the Cambrian explosion. All of the 100 to 110 species of this phylum are obligatory parasites of vertebrates (almost all are terrestrial, although a few species live on fishes). Like many parasites, pentastomes have a complex life cycle, moving from an intermediate to a final host. Larvae bore through the gut wall of the first host, where they mature to their infective stage. When another vertebrate eats this first host, the mature pentastome moves to the respiratory tract, either by crawling from the stomach to the esophagus and boring through, or by tunneling through the intestinal wall and into the blood stream. The parasite then attaches to the lungs, nasal cavity or oral cavity (some pentastomes have even been reported from human eyes), by means of hooks at the end of the two pairs of limbs surrounding the mouth. In this (now) permanently attached feeding stage, the pentastome uses its mouth to suck the host's blood. (For most people, nothing in biology sounds more, well, to use the contemporary vernacular, yucky than the life styles of parasites; but such creatures do form a major component of life's diversity and ecology, and we do need to understand them, although I advance no case for loving them.)

Like many parasites, pentastomes are extremely simplified in anatomy (for the safe and sheltered environment of a host specifies little advantage for retaining the complex features needed for life in the tougher external world). The specific organs of parasitic life—the means of finding, attaching to, and exploiting hosts—are present and complex (in this case, the five star arrangement of the stalked mouth and two pairs of legs at the front end), but the rest of the body is secondarily simplified. Pentastomes have, for example, no internal organs for respiration, circulation, or excretion. The gut is a simple straight tube, with a muscular pumping apparatus at the front end, obviously useful in extracting the host's blood.

Nature abhorring a vacuum

This extreme anatomical simplification of ordinary organs, combined with elaboration of highly specific devices for exploiting hosts, makes the taxonomy of parasites, and their genealogical placement into the evolutionary tree of free-living forms, particularly difficult. Pentastomes have long provided a classical example of this general nightmare in taxonomy. The range of available hypotheses spans nearly all conceivable solutions, with links to annelids (segmented worms), arthropods of one subgroup or another, and separate status (often joined with onychophores and tardigrades) as the favored solutions.

In recent years, however, a consensus had arisen for allying pentastomes with crustaceans of the arthropod phylum. Several authors had presented evidence of similarity between larvae of pentastomes and a group of crustaceans known as branchiurans. Fine structure of the external cuticle and morphology of the sperm cells also seemed to affirm a crustacean link. Then, in 1989, a sealing argument seemed to emerge from the laboratory of my friend and colleague Larry Abele, of Florida State University (*see* L. G. Abele, W. Kim, and B. E. Felgenhauer, "Molecular Evidence of Inclusion of the Phylum Pentastomida in the Crustacea," *Molecular Biology and Evolution,* vol. 6). Abele and associates used the most powerful and appropriately fashionable technique of comparing DNA sequences (in the commonly used and highly informative molecule 18S ribosomal RNA) in pentastomes and representatives of several candidate phyla for relationships—segmented worms and all major groups of arthropods, including insects, horseshoe crabs, millipedes, and crustaceans. The evolutionary tree reconstructed from molecular distances revealed a closest tie of pentastomes with crustaceans. These data led Brusca and Brusca to argue in their textbook for "convincing cases that pentastomids are actually highly modified crustacean parasites."

Moreover, the current life of pentastomes in terrestrial vertebrates led all

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What is ROGAINE?
ROGAINE Topical Solution is a prescription medicine for use on the scalp that is used to treat a type of hair loss in men and women known as androgenetic alopecia: hair loss of the scalp vertex (top or crown of the head) in men and diffuse hair loss or thinning of the front and top of the scalp in women. ROGAINE is a topical form of minoxidil, for use on the scalp.

How effective is ROGAINE?
In men: Clinical studies with ROGAINE of over 2,300 men with male pattern baldness involving the top (vertex) of the head were conducted by physicians in 27 US medical centers. Based on patient evaluations of regrowth at the end of 4 months, 26% of the patients using ROGAINE had moderate to dense hair regrowth compared with 11% who used a placebo treatment (no active ingredient). No regrowth was reported by 41% of those using ROGAINE and 58% of those using a placebo. By the end of 1 year, 48% of those who continued to use ROGAINE rated their hair growth as moderate or better.

In women: A clinical study of women with hair loss was conducted by doctors in 11 US medical centers. Based on patients' self-ratings of regrowth after 32 weeks, 59% of the women using ROGAINE rated their hair regrowth as moderate (19%) or minimal (40%). For comparison, 40% of the women using placebo (no active ingredient) rated their hair regrowth as moderate (7%) or minimal (33%). No regrowth was reported by 41% of the group using ROGAINE and 60% of the group using placebo.

How soon can I expect results from using ROGAINE?
Studies show that the response time to ROGAINE may differ greatly from one person to another. Some people using ROGAINE may see results faster than others; others may respond with a slower rate of hair regrowth. You should not expect visible regrowth in less than 4 months.

How long do I need to use ROGAINE?
ROGAINE is a hair-loss treatment, not a cure. If you have new hair growth, you will need to continue using ROGAINE to keep or increase hair regrowth. If you do not begin to show new hair growth with ROGAINE after a reasonable period of time (at least 4 months), your doctor may advise you to discontinue using ROGAINE.

What happens if I stop using ROGAINE? Will I keep the new hair?
Probably not. People have reported that new hair growth was shed after they stopped using ROGAINE.

How much ROGAINE should I use?
You should apply a 1-mL dose of ROGAINE twice a day to your clean dry scalp, once in the morning and once at night before bedtime. Wash your hands after use if your fingers are used to apply ROGAINE. ROGAINE must remain on the scalp for at least 4 hours to ensure penetration into the scalp. Do not wash your hair for at least 4 hours after applying it. If you wash your hair before applying ROGAINE, be sure your scalp and hair are dry when you apply it. *Please refer to the Instructions for Use* in the package.

What if I miss a dose or forget to use ROGAINE?
Do not try to make up for missed applications of ROGAINE. You should restart your twice-daily doses and return to your usual schedule.

What are the most common side effects reported in clinical studies with ROGAINE?
Itching and other skin irritations of the treated scalp area were the most common side effects directly linked to ROGAINE in clinical studies. About 7 of every 100 people who used ROGAINE (7%) had these complaints.

Other side effects, including light-headedness, dizziness, and headaches, were reported both by people using ROGAINE and by those using the placebo solution with no minoxidil. You should ask your doctor to discuss side effects of ROGAINE with you.

People who are extra sensitive or allergic to minoxidil, propylene glycol, or ethanol should not use ROGAINE.

ROGAINE Topical Solution contains alcohol, which could cause burning or irritation of the eyes or sensitive skin areas. If ROGAINE accidentally gets into these areas, rinse the area with large amounts of cool tap water. Contact your doctor if the irritation does not go away.

What are some of the side effects people have reported?
ROGAINE was used by 3,857 patients (347 females) in placebo-controlled clinical trials. Except for dermatologic events (involving the skin), no individual reaction or reactions grouped by body systems appeared to be more common in the minoxidil-treated patients than in placebo-treated patients.

Dermatologic: irritant or allergic contact dermatitis—7.36%; **Respiratory:** bronchitis, upper respiratory infection, sinusitis—7.16%; **Gastrointestinal:** diarrhea, nausea, vomiting—4.33%; **Neurologic:** headache, dizziness, faintness, light-headedness—3.42%; **Musculoskeletal:** fractures, back pain, tendinitis, aches and pains—2.59%; **Cardiovascular:** edema, chest pain, blood pressure increases/decreases, palpitations, pulse rate increases/decreases—1.53%; **Allergic:** nonspecific allergic reactions, hives, allergic rhinitis, facial swelling, and sensitivity—1.27%; **Metabolic-Nutritional:** edema, weight gain—1.24%; **Special Senses:** conjunctivitis, ear infections, vertigo—1.17%; **Genital Tract:** prostatitis, epididymitis, vaginitis, vulvitis, vaginal discharge/itching—0.91%; **Urinary Tract:** urinary tract infections, renal calculi, urethritis—0.93%; **Endocrine:** menstrual changes, breast symptoms—0.47%; **Psychiatric:** anxiety, depression, fatigue—0.36%; **Hematologic:** lymphadenopathy, thrombocytopenia, anemia—0.31%.

ROGAINE use has been monitored for up to 5 years, and there has been no change in incidence or severity of reported adverse reactions. Additional adverse events have been reported since marketing ROGAINE and include eczema; hypertrichosis (excessive hair growth); local erythema (redness); pruritus (itching); dry skin/scalp flaking; sexual dysfunction; visual disturbances, including decreased visual acuity (clarity); increase in hair loss; and alopecia (hair loss).

What are the possible side effects that could affect the heart and circulation when using ROGAINE?
Serious side effects have not been linked to ROGAINE in clinical studies. However, it is possible that they could occur if more than the recommended dose of ROGAINE were applied, because the active ingredient in ROGAINE is the same as that in minoxidil tablets. These effects appear to be dose related; that is, more effects are seen with higher doses.

Because very small amounts of minoxidil reach the blood when the recommended dose of ROGAINE is applied to the scalp, you should know about certain effects that may occur when the tablet form of minoxidil is used to treat high blood pressure. Minoxidil tablets lower blood pressure by relaxing the arteries, an effect called vasodilation. Vasodilation leads to fluid retention and faster heart rate. The following effects have occurred in some patients taking minoxidil tablets for high blood pressure:

Increased heart rate: some patients have reported that their resting heart rate increased by more than 20 beats per minute.
Salt and water retention: weight gain of more than 5 pounds in a short period of time or swelling of the face, hands, ankles, or stomach area.
Problems breathing: especially when lying down; a result of a buildup of body fluids or fluid around the heart.
Worsening or new attack of angina pectoris: brief, sudden chest pain.

When you apply ROGAINE to normal skin, very little minoxidil is absorbed. You probably will not have the possible effects caused by minoxidil tablets when you use ROGAINE. If, however, you experience any of the possible side effects listed above, stop using ROGAINE and consult your doctor. Any such effects would be most likely if ROGAINE was used on damaged or inflamed skin or in greater than recommended amounts.

In animal studies, minoxidil, in much larger amounts than would be absorbed from topical use (on skin) in people, has caused important heart-structure damage. This kind of damage has not been seen in humans given minoxidil tablets for high blood pressure at effective doses.

What factors may increase the risk of serious side effects with ROGAINE?
People with a known or suspected heart condition or a tendency for heart failure would be at particular risk if increased heart rate or fluid retention were to occur. People with these kinds of heart problems should discuss the possible risks of treatment with their doctor if they choose to use ROGAINE.

ROGAINE should be used only on the balding scalp. Using ROGAINE on other parts of the body may increase minoxidil absorption, which may increase the chances of having side effects. You should not use ROGAINE if your scalp is irritated or sunburned, and you should not use it if you are using other skin treatments on your scalp.

Can people with high blood pressure use ROGAINE?
Most people with high blood pressure, including those taking high blood pressure medicine, can use ROGAINE but should be monitored closely by their doctor. Patients taking a blood pressure medicine called guanethidine should not use ROGAINE.

Should any precautions be followed?
People who use ROGAINE should see their doctor 1 month after starting ROGAINE and at least every 6 months thereafter. Stop using ROGAINE if any of the following occur: salt and water retention, problems breathing, faster heart rate, or chest pains.

Do not use ROGAINE if you are using other drugs applied to the scalp such as corticosteroids, retinoids, petrolatum, or agents that might increase absorption through the skin. ROGAINE is for use on the scalp only. Each 1 mL of solution contains 20 mg minoxidil, and accidental ingestion could cause unwanted effects.

Are there special precautions for women?
Pregnant women and nursing mothers should not use ROGAINE. Also, its effects on women during labor and delivery are not known. Efficacy in postmenopausal women has not been studied. Studies show the use of ROGAINE will not affect menstrual cycle length, amount of flow, or duration of the menstrual period. Discontinue using ROGAINE and consult your doctor as soon as possible if your menstrual period does not occur at the expected time.

Can ROGAINE be used by children?
No, the safety and effectiveness of ROGAINE has not been tested in people under age 18.

Caution: Federal law prohibits dispensing without a prescription. You must see a doctor to receive a prescription.

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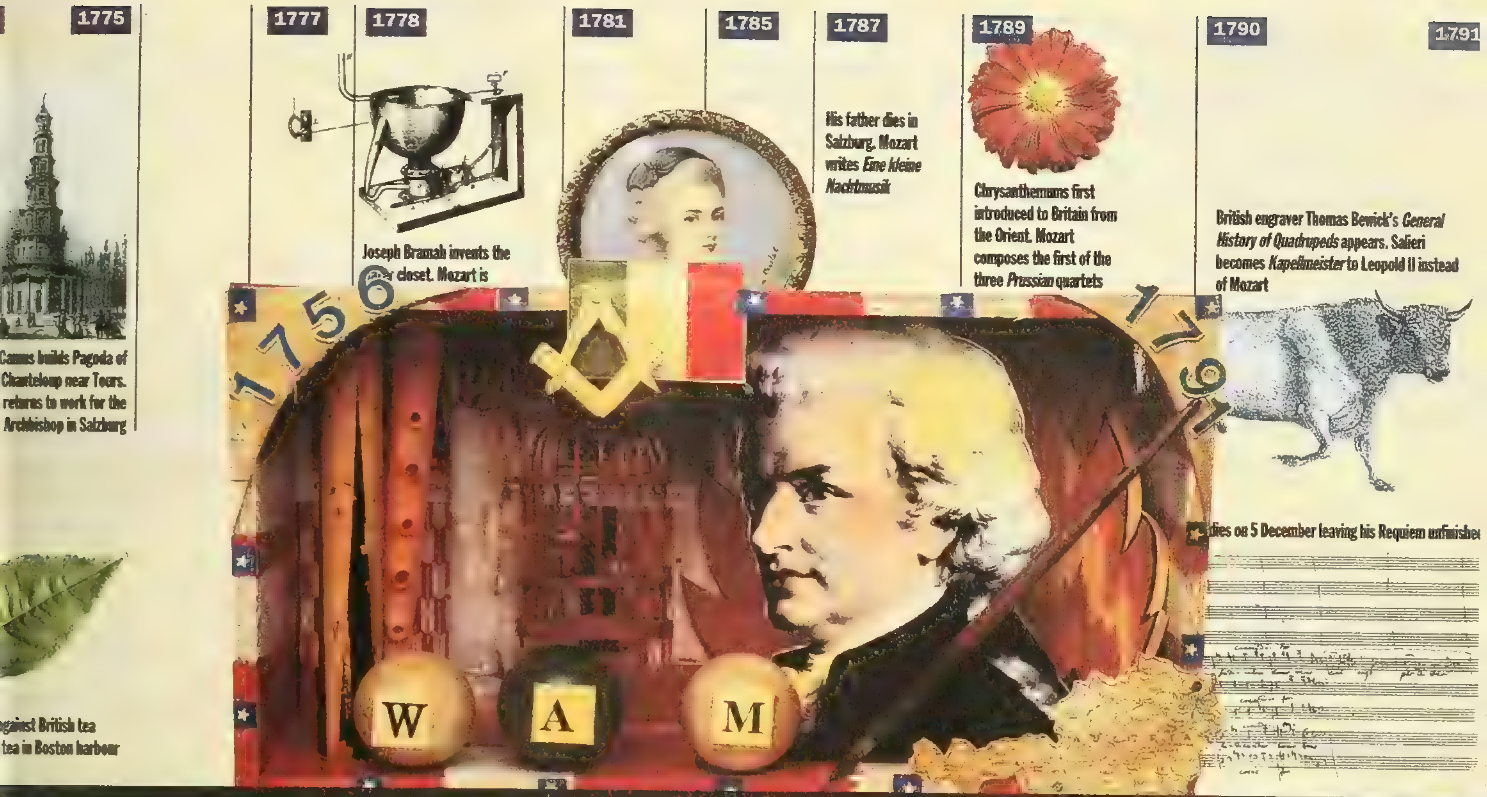
these exponents of a crustacean link to the reasonable hypothesis that pentastomes originated long after the Cambrian explosion, thus affirming the conventional view that fundamentally new body plans may originate throughout geological time, and that the Cambrian explosion is a great episode of intensification, but not an exclusivity. In fact, Abele and colleagues proposed a divergence date of 350 to 225 million years ago for pentastomes and crustaceans.

But Walossek and Müller have now described indisputable pentastomes—a whole fauna of several species, not just a single example—from upper Cambrian strata (*see* Dieter Walossek and Klaus J. Müller, "Pentastomid Parasites from the Lower Paleozoic of Sweden," *Transactions of the Royal Society of Edinburgh, Earth Sciences,* vol. 85, 1994). These fossils come from the upper Cambrian "Orsten" beds of Sweden, an extraordinary deposit that has, over the last two decades, yielded a vitally important fauna of tiny, exquisitely beautiful fossils from this early time in the history of multicellular animal life. (The fossils are phosphatized and preserved in tiny calcareous nodules. The nodules can be dissolved away in acid, leaving a perfectly formed and fully three-dimensional fossil, hollow on the inside but recording all elaborate and intimate detail of the surface architecture. Unfortunately, since the nodules are so tiny, no fossil of more conventional and larger marine invertebrates can be preserved, and the Orsten fauna consists primarily of arthropod larvae and other tiny adult creatures including these newly described pentastomes.)

In all such cases of proposed linkage between ancient fossils and living forms (especially in the face of such a temporal gap, for no later pentastome fossils are known between these ancient Orsten specimens and the living species), one must consider the obvious alternative that the fossils are merely convergent upon modern pentastomes and represent an entirely independent genealogical line. The history of life is replete with examples of astonishing similarity separately evolved—fish and ichthyosaurs, marsupial and placental moles, eyes of squid and vertebrates. But convergence, however stunning in general adaptive features of basic form and function, can never be intricately precise in hundreds of detailed and highly particular parts—because converging lines begin from such different antecedents and must craft similarities from disparate starting


1775
Camus builds Pagoda of Chanteloup near Tours.
returns to work for the Archbishop in Salzburg
1777
1778
Joseph Bramah invents the
r closet. Mozart is
1781
1785
1787
His father dies in Salzburg. Mozart writes *Eine kleine Nachtmusik*
1789
Chrysanthemums first introduced to Britain from the Orient. Mozart composes the first of the three *Prussian* quartets
1790
British engraver Thomas Bewick's *General History of Quadrupeds* appears. Salieri becomes *Kapellmeister* to Leopold II instead of Mozart
1791
1756
1791
dies on 5 December leaving his Requiem unfinishe
gainst British tea
tea in Boston harbour
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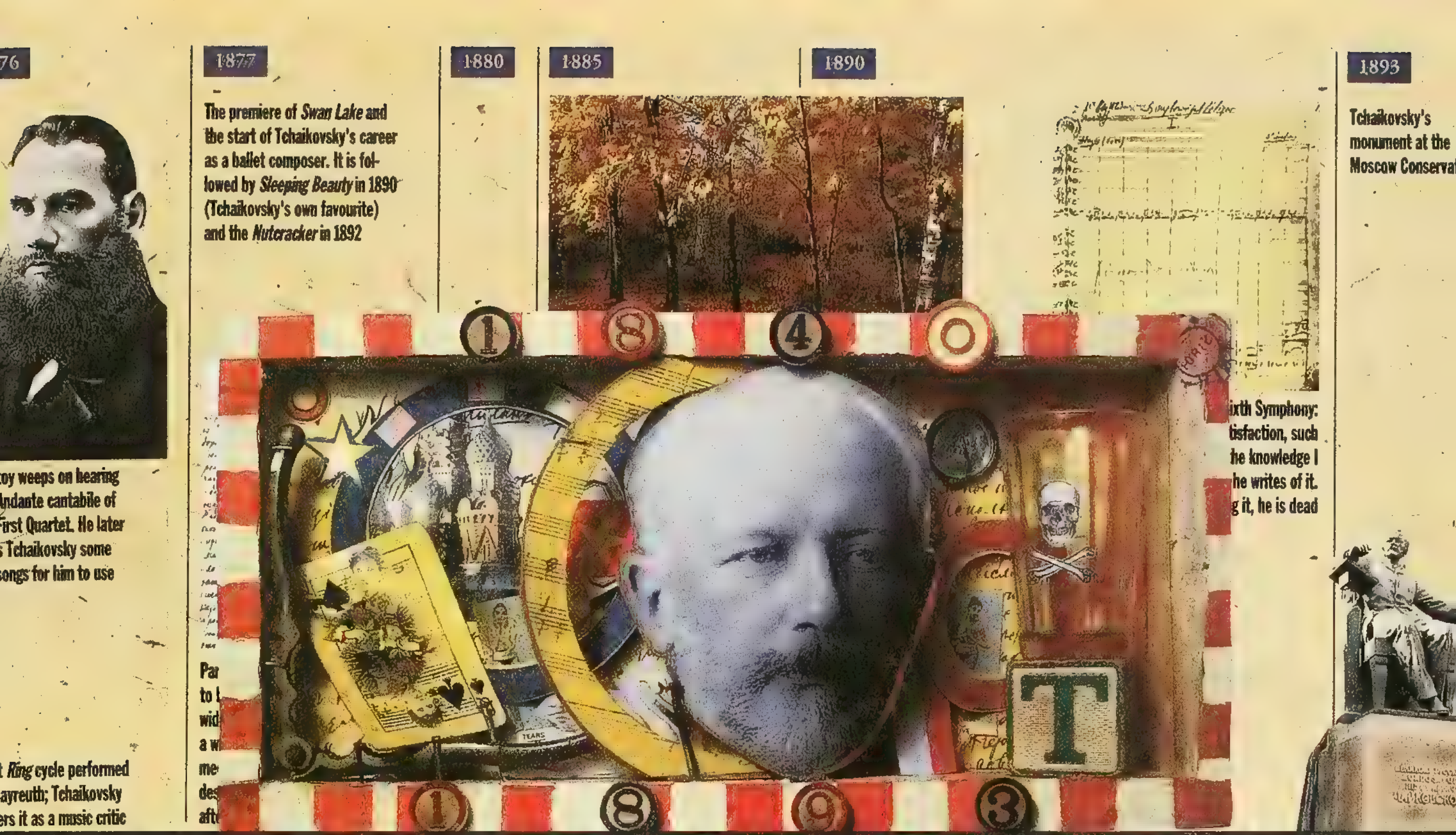
76
1877
The premiere of *Swan Lake* and the start of Tchaikovsky's career as a ballet composer. It is followed by *Sleeping Beauty* in 1890 (Tchaikovsky's own favourite) and the *Nutcracker* in 1892
1880
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Tchaikovsky's monument at the Moscow Conserva
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ixth Symphony: tisfaction, such he knowledge I he writes of it. g it, he is dead
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points. Thus, ichthyosaur paddles may be dead ringers for fish fins in external form, but they are built of finger bones from a terrestrial past; and the eyes of squid and vertebrates, although so similar in final form, follow markedly different embryological routes in their construction.

We may be confident that Walossek and Müller's specimens are true pentastomes because (as for their tardigrades) the similarities are so numerous, so detailed, and so pervasive. These features include the basic body plan of a globular head with two pairs of limbs suited for attachment to a host, and a thin, tapering, wormlike body behind. Fossils and moderns also share the basic embryological design of "segment constancy," with growth in size through successive molts, but no addition of further segments (as insects and most arthropods generally do) in growth. (The Orsten fossils include both larvae and adults, so even these details of growth may be inferred.)

Beyond this identity of basic form and growth, fossils and moderns also match part for apparently trivial part. Both have distinctive pores on the inner edges of the limbs; both can withdraw the limbs partially into their sockets; both grow a pair of papillae, or nodes, at the rear end surrounding the anus. Such a suite of distinct and apparently minor features would not evolve twice in such detailed similarity of form and position.

Moreover, in one prominent feature, the fossils teach us something important by revealing a structure unknown in modern forms. The body of modern pentastomes (behind the head) seems to consist of four segments. But these divisions are not marked by clearly repeating structures in each zone—the usual sign of true segmentation in several invertebrate phyla. Nerve ganglia are separated and repeated, but since pentastomes are so morphologically degenerate (with no respiratory, circulatory, or excretory organs), few other possibilities exist for crucial evidence of true segmentation. In particular, the most indicative of all features—limbs on each segment—do not exist in any modern pentastome. But several of the fossils contain small, paired limbs on the second and third body segments! In fact, one might say that the fossils are entirely comparable to the moderns, with this one added (and highly informative) feature.

These fossils clearly disprove the favored hypothesis of later derivation for pentastomes after the evolution of terrestrial vertebrates. Of the pentastomes' profound stability for more than 500 million years, Walossek and Müller conclude: "The long history of the group and its remarkable morphological stasis invalidates any hypothesis of their evolution from terrestrial arthropods" (for arthropods did not invade the land until long after the Cambrian).

The existence of Cambrian pentastomes raises the obvious question of their original hosts, since terrestrial vertebrates had not yet evolved. Switching of hosts, even from one phylum to another, is a common phenomenon in the evolution of parasites, so the need to postulate such a transition raises no theoretical problems, but we still want to know the potential candidates. The original Cambrian hosts need not have been closely related to vertebrates, but one prominent fossil group, the conodonts, has been enigmatic throughout the history of paleontology (for their soft bodies provide little opportunity for fossilization and only their microscopic "tooth elements" are generally preserved). But soft-bodied remains of entire animals have been found in the last decade and latest evidence indicates that conodonts belonged to the vertebrates after all, as Walossek and Müller suggest. Conodont fossils are common in all Cambrian localities that have yielded pentastomes.

But what of the biochemical claims for crustacean affinities and origin much later than the Cambrian? Molecular data have won such prestige over the last few years that such a contention might seem indisputable—yet the hard evidence of Cambrian pentastomes seems even less subject to refutation. But close reading of Abele's 1989 paper provides a lovely resolution.

I have often pointed out in these essays how theories strongly constrain (often unconsciously) our interpretation of data. (For this reason we must be particularly vigilant and probing as we explicitly consider the consequences of our theoretical preferences.) The solution lies in the last sentence of the paper by Abele and colleagues—but they didn't see it, presumably because later origin from crustaceans fit the usual assumptions of evolutionary theory and its preference for continuous origin of major groups. The last line reads (I will quote verbatim and then translate):

> Thus, over a period of time very roughly estimated to be 287 . . . million years, the 18S rRNA of these two groups has diverged about 10.8 percent, or about 1.9 percent per fifty million years, a higher rate than the one percent per fifty million years previously reported for eucaryote 18S rRNA. Given the potential errors in making such estimates the significance of this difference remains unknown.

In other words, assuming that pentastomes arose only 287 million years ago from crustaceans, the rate of evolution for their RNA is nearly twice as fast as average rates calculated for other multicellular organisms. This doesn't trouble them too much (as the very last sentence states) because RNA rates are subject to so much error.

But they never even mention the obvious alternative hypothesis—which now turns out to be almost certainly correct. If the pentastomes really diverged from crustaceans (or from some other group) during the Cambrian, some 530 rather than 287 million years ago, then the total measured difference does not translate to an unusually high rate of change, but to an average rate after all—for the 10.8 percent difference, spread over 530 rather than 287 million years, works out to just about the average of 1 percent over 50 million years! In other words, the molecular data and the fossil evidence coincide and remove an anomaly in the molecular data considered alone under the conventional (and false) assumption of later origin for the minor phyla.

The Cambrian explosion is the key event in the history of multicellular animal life. The more we study this episode, the more we are impressed by its uniqueness and of its determining effect on the subsequent pattern of life's history. The basic anatomies that arose during the Cambrian explosion have dominated life ever since, with no major additions—and with subtractions imposed for reasons that may more resemble the luck of the draw than the predictable survival of superior lines. The pattern of life's history has followed from the origins and successes of this great initiating episode. I can, therefore, only end with another well-remembered line from Gettysburg, when Lincoln so misspoke in the first phrase (a cruel irony for schoolchildren forced to memorize against their will), but stated so truly and eloquently in the second—and which applies so well to the extraordinary influence of successful Cambrian groups: "The world will little note nor long remember what we say here, but it can never forget what they did here."

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

Go Figure

How I learned to stop worrying and love soccer

by Roger L. Welsch

I once went six years without balancing my checkbook. The prospect of dealing with all those numbers was so threatening that, when my finances finally collapsed, I just closed all the accounts and started over. I'd consider that embarrassing, but I know that I am not alone. Americans hate numbers. Numbers, which by their very nature should be incontrovertible, carry no weight whatsoever with huge segments of the population, and if you don't believe me, next time you're driving on a freeway, slow down enough to read one of those speed limit signs. I know people who would rather talk to their children about sex than help them with a mathematics assignment.

At least that's what I used to think. Last summer I was watching a World Cup Soccer match on television with a friend who knows his way around the American sports scene. I like soccer, an elegant dance of skill and endurance, and am utterly baffled by the appeal of American football, which consists of spasms of extreme violence devoid of grace and nuance. If ever there was going to be a chance to sort out my confusion, I figured this was it. "Bud," I said, "I understand all the talk about how the low scoring in soccer puts it at a disadvantage in America, but hockey does all right here. What's the problem with soccer?"

"No stats," my friend Bud explained.

"Huh?" I probed.

"No stats. Americans don't like sports. They like stats. The problem with soccer is not that it doesn't have a lot of scoring, and Americans like scoring. Americans like statistics, and scoring generates lots of stats."

It is a curious contradiction for a nation notorious for its ignorance, dislike, and distrust of numbers and mathematics, but Bud may be right: we may not like numbers just lying there naked on a page, the kind of numbers we associate in our subpsyches with the IRS, but we love numbers put into the form of statistics. News magazines now have a little box of statistics for almost every page of print.

—Number of Americans who approve of the coverage of comet fragments bombarding Jupiter: 40 percent approve, 40 percent disapprove, 20 percent recommend using a comet-cam to get a better action shot.

—Number of Americans who want reform of the health care system: 36 percent; number of congressional representatives who want reform of the health care system: 36 percent; number of Americans who want a congressperson's health care system: 100 percent.

—Americans 100 percent, Belgians 3 percent, black labs 33 percent, pipe fitters 77 percent.

Americans who don't know or care about the difference between a knuckle ball and a knuckle sandwich were distressed about last summer's baseball strike because of the irreparable damage it did to the statistics of the game. For all eternity, the horror story went, sportscasters would be doomed to saying things like, "This season Maury Spiegel has set an all-time record for left-handed shortstops wearing a glove with two middle fingers on the outside by catching the fewest pop-ups hit by right-handed batters named Boog in their first year in the majors—*except,* of course, for the short season of 1994, when there were so few games that no one caught any pop-ups by right-handed bat-

TARZAN OF THE URBAN JUNGLE

ters named Boog playing their first year in the majors."

What does it really matter, after all, if the 1994 champions of the game win a total of twelve games as is the case in the NFL or 9,663 games like they do in the NBA? The reason people were upset by the strike was that it messed up the statistics. It's like having to say, "Yep, I have every copy of *Natural History* I've received since I was ten years old, and my subscription started in 1933. Uh, except for the December 1944 issue."

The problem is not that there are no potential statistics in soccer; it's just that we have not developed a canon of ratios, proportions, rates, contrasts, and comparisons. We need that set of stats to give the sport an air of precision and science and elevate its adherents from the role of "fanatic" to "fan," from "dumb jock" to "color commentator." We need numbers for guys in taverns and bars to remember and argue about. The good news is that stats can be nurtured and molded and coaxed into being. It doesn't matter if angels do or don't dance on the head of a pin; the point is to estimate how many there would be if they did.

You can imagine my delight therefore when I discovered that one of my favorite sources of information about the world of science (or the world, for that matter), *Spy* magazine, is hard at work on the problem. In the September/October 1994 issue, the editors both posed the problem with soccer ("After 120 minutes, Italy and Brazil, 0-0. If America slept through the World Cup, maybe it's because we're used to seeing our teams score once in a while") and took a giant step toward easing our ennui:

> Two statistics tell the story: (1) Of the 206 games played in the qualifying round, 120 were shutouts, including 20 scoreless ties; (2) 44% of the players qualifying for the 1994 World Cup (excluding goaltenders) have never scored a goal in international competition.

Now, see? Don't all those numbers and the percentage sign make you start to feel better already? But *Spy* knows that we also crave statistics regarding individual players. For example, one forward from Spain has played twenty international games without scoring, a total of thirty straight hours of scoreless competition.

"Surely," *Spy* observes, "the typical World Cup soccer player doesn't need *30 hours* to score a goal." The article proceeds to examine this point, building a beautiful chart based on the scoring of players who were in the World Cup games. For example,

—Samson Siasia, Nigeria: 50 matches and 40 goals, or 1 hour, 52 minutes, 30 seconds per goal.

—Jan Wouters, Netherlands: 64 matches and 4 goals, or 1 day per goal.

—Desmond Armstrong, United States: 83 matches and 0 goals, or 5 days, 4 hours, 30 minutes per goal ("and counting").

And so on. Add a few calculations about the number of hot dogs sold at games in Dallas and Seattle with chili and those with relish, pie charts graphically showing the gallons of beer consumed during a game between the Germans and the Irish compared with the volume of suds downloaded during a match between the Saudis and French, and maybe even a statistic or two directly related to the game, perhaps a poll of television viewers quantifying preferences for uniform colors, and hey, now we're talking sports! And, one might add, mathematics.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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Why I Will Continue to Eat Corn Smut

To farmers, it's a blight, but to gastronomes, it's a delicacy

by Robert Sommer

When I spied *huitlacoche* on the menu of the elegant Cafe Beaujolais, in Mendocino, California, the name looked familiar, but I could not recall whether I had read it first in a book about Mexican cookery or in a mushroom guide. When questioned, the waiter described the dish as Mexican crêpes, containing chilis and mushrooms and covered in *mole,* a chocolate-chili sauce whose invention is credited to nuns in a convent in Puebla, Mexico, two centuries ago. I inquired if the mushroom ingredient was corn smut (*Ustilago maydis*). The waiter recoiled and made an immediate denial. When I persisted, he retreated to the kitchen to consult with higher authority, returning a few minutes later to acknowledge that the chef had complimented my culinary knowledge and confirmed that the major ingredient of *huitlacoche* was what I had described. We then ordered and consumed it with gusto.

I encountered corn smut as a menu item again in Mexico City, this time spelled *cuitlacoche*. It was a filling for quesadillas and tasted rich, earthy, and somewhat gritty, with a distinctive fungal quality. Visually, it was a dark, unappealing mass.

As an amateur mycologist, I consulted the major field guides to fungi. Most did not even mention *U. maydis,* a fungus that first appears on the corn kernel as a whitish growth and, after a few days, becomes a bluish gray, grainy boil (growing up to three-quarters of an inch long) before rupturing and releasing black "soot," as do puffballs. A statement in one guide mentioned *U. maydis* as a highly regarded food item in Mexico, while another, David Arora's 1990 *All That the Rain Promises and More: A Hip Pocket Guide to Western Mushrooms,* featured a two-page color spread extolling the culinary properties of *U. maydis*. According to Arora, *U. maydis* is so highly regarded as a food item in Mexico that farmers welcome the appearance of smut in their corn fields. What about American farmers?

Davis, California, where I live, is a rich agricultural region with tall corn fields lining the country roads. I decided that corn smut must be available, especially from organic growers at the local market, whose corn typically contains green worms in the tassels and occasionally the bluish galls, or boils, that indicate corn smut. One week in September toward the end of the sweet corn season, I noticed a few small galls on the corn sold to me by Jeff Main, one of the founders of the Davis Farmers' Market.

Since I have known Jeff for many years, and he tolerates my occasional odd query, the following week I made it a point to inquire about the smut when no other customers were around, assuring him that I was not dissatisfied with last week's corn and, in fact, would like more of the same if he had any. The next day, instead of a few ears of infected corn, he delivered ten bushels to my doorstep. Having previously seen only a few bluish gray boils on

A threshing machine burns on a farm outside Pullman, Washington, 1914. Highly flammable, smut dust caused many such explosions in the region.
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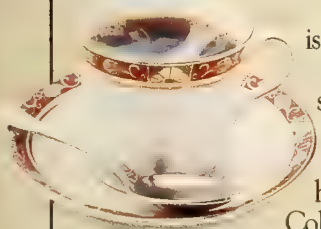

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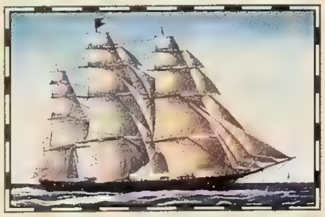

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an occasional ear, I had no idea what to do with such a large quantity, but knew I had to work quickly because the best time for eating fungi is usually before the spores mature. Already, many of the smut boils had ripened, discharging clouds of black spores.

Arora's recipe, the only one in my library, had been borrowed from Diana Kennedy's popular book *The Art of Mexican Cooking*. It called for six cups of roughly cut smutted corn (as whole as possible to preserve the texture) and four charred, peeled, seeded, and sliced *chiles poblanos*. After frying two tablespoons of finely chopped white onion and garlic cloves in three tablespoons of safflower oil, I was to mix in the smut kernels and chiles, cooking the whole batch fifteen minutes over medium heat until tender and moist (but not soft and mushy). The only recipe ingredient that I lacked was two tablespoons of *epazote*, or Mexican tea leaves (which were to be added in the last two minutes of cooking). I decided to proceed without them.

Removing the smut boils was a dirty business because some of them had ruptured. Clouds of spore soot soon blackened my hands and clothing, and I had visions of tiny corn stalks rooting in my respiratory system from breathing in the stuff. But I did manage to remove a goodly quantity of bluish kernels, and when my wife, Barbara, returned a few hours later, she was amazed to find two vats of *huitlacoche* cooking away on the stove, and a large bucket of corn smut in the refrigerator. Not only did we have enough *huitlacoche* for the evening's dinner, plus leftovers, but Barbara also filled eighteen freezer bags.

The dish was delicious, and the wonderful world of corn smut had been revealed. Through my connections with local organic growers, I could probably obtain a continuing supply and turn a grower's economic liability into an asset. Visions of organic farmers delivering baskets of corn smut to fancy restaurants and upscale produce markets danced through my head. Perhaps I might have a role in this new product's development, becoming known as the father of smut.

I needed to know more about this delicacy's background, however, and so turned to the library at the University of California at Davis. Because Davis is a land grant institution with deep agricultural roots, its botany collection is excellent, and among the numerous volumes on mycology, perhaps a dozen books were devoted to rusts and smuts.

An estimated 1,200 species of smut infect more than 4,000 species of host plants, including almost all cereal crops, plus beans and flowering plants such as violets, gladioli, and dahlias. The smut fungi produce a variety of symptoms on their hosts, sometimes affecting roots, stems, leaves, or flowers. For the corn smut genus, *Ustilago,* more than 350 species have been identified, but *U. maydis* rates no more than a paragraph or two in most books. Probably the reason for its neglect is that its host is a New World plant and relatively new to the literature since smut records go back to antiquity.

Smut boils ripen on corn kernels and eventually release a cloud of black spore dust.
Rob and Melissa Simpson

Some authorities believe that smut infestation was responsible for the periodic migrations of the Hebrews and other early peoples. The ancient Greeks thought the grain-destroying smut fungus *Tilletia caries* was caused by solar rays that burned the grain after a period of rain. Roman documents blamed smut for extensive damage to crops and for resultant famines.

An advance in smut control came as a result of the accidental sinking of a vessel loaded with wheat off Bristol, England, in 1670. Farmers used the salvaged wheat, which was soaked with saltwater, as seed since it didn't seem good for anything else. At the next harvest, they discovered that the brine-soaked wheat was free from *T. caries,* which they called bunt. The practice of dipping wheat seed into a brine solution continued for the next hundred years.

In 1750, the Bordeaux Academy of Arts and Sciences offered a prize for "the best dissertation on the causes and cures of wheat blackening." Mathieu Tillet, master of the mint at Troyes, deliberately contaminated seeds with dust from smut boils and produced "bunted" wheat. Tillet, however, was unsuccessful in similar experiments trying to prove the infectious quality of smut boils in corn. Finally, more than a hundred years later, Oscar Brefeld, rather than coating seed with smut spores as Tillet had done, sprayed young corn plants with *U. maydis* spores, causing the development of smut boils on the mature ears.

In the meantime, in 1807 in Montauban, France, Benedict Prevost looked at bunt spores under a microscope and identified them as a fungus. He then set about finding suitable control measures. Visiting a nearby farm, Prevost noticed peasants soaking seeds in an old copper pot containing a mixture of sheep's urine, lime, and water. Unimpressed by the urine and lime mixture, Prevost immersed a piece of polished copper into water containing bunt spores, and the spores died. He found the same results could be achieved with a solution of copper sulfate.

The historical information on smut control did not prepare me for the graphic descriptions of smut explosions. George Zundel, who wrote the authoritative treatise, *The Ustilaginales of the World* (published posthumously in 1953), first became interested in smut when he was a boy working at his grandfather's farm. At harvest time, he observed a black cloud emerging from the rear of the threshing machine. His grandfather identified the

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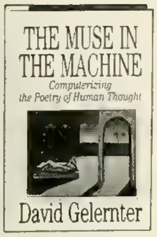
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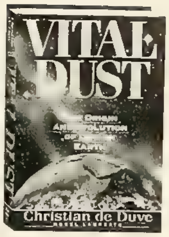
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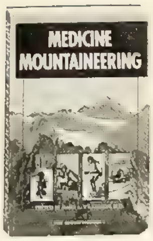
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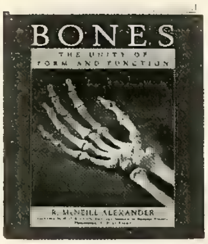
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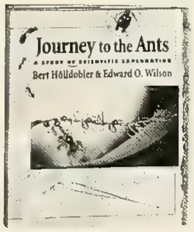
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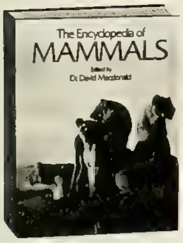
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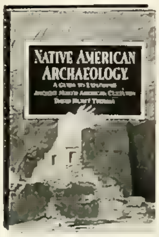
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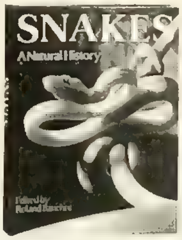
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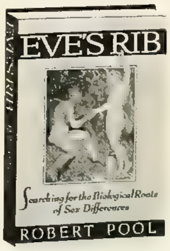
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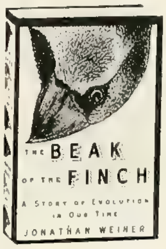
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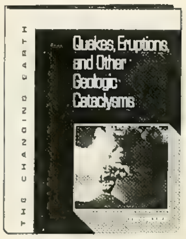
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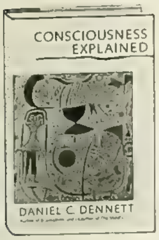
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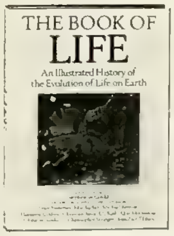
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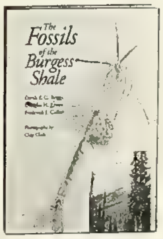
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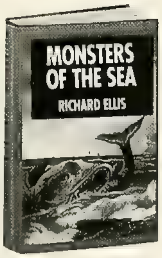
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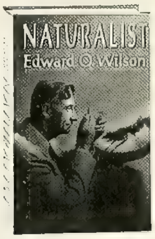
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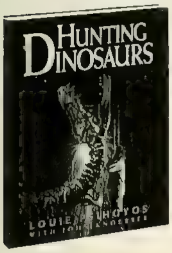
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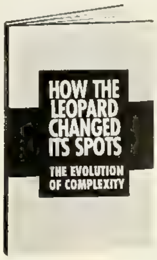
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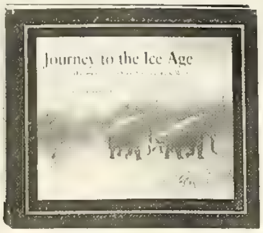
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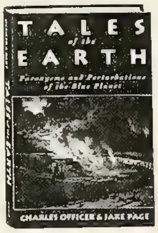
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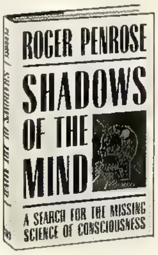
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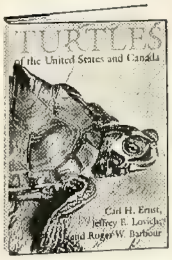
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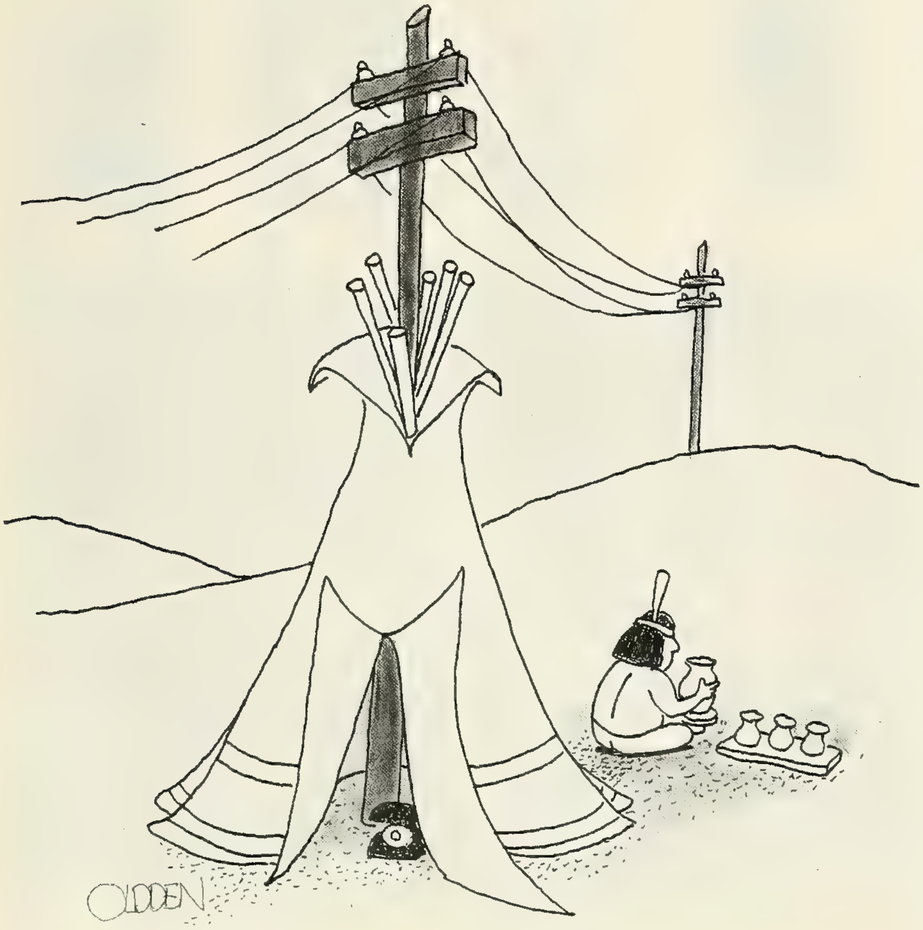
"dust" as smut, which deformed many grain cereals. Intrigued, Zundel went on to study smut at agricultural school.

His research was stimulated by the economic significance of smuts. In 1918, *U. maydis* destroyed enough corn to equal the entire crops of Indiana and Maryland combined. Smut explosions, common in wheat-growing areas of eastern Washington and Oregon and northern Idaho, had sizable economic costs. In one county in Washington State, Zundel reported nearly 300 large threshing separators exploding and burning at harvest season due to smut fires. Static electricity and, occasionally, sparks from threshing machines would ignite smut dust, which was more explosive than coal dust. If they did not explode, large black clouds that emerged from the threshing machines would be dispersed by the winds as "smut showers" covering large areas.

In reading the material on the damage caused by *U. maydis,* I was anxious to move on to its use as food. When I mentioned its culinary possibilities to other people, the response was negative. Even well-educated people seemed to believe that smut was poisonous. But was it? If people were allergic to the spores, what would happen? Could corn smut be eaten a few times without ill effects? What about regular consumption?

Technical books on smuts and rusts contain contradictory information about their effects upon humans and animals. Accounts of toxicity of infected grain, particularly ergot fungus on rye, go back to mass poisonings in the Middle Ages and are also referred to occasionally in the twentieth century. Some of the earlier anecdotal accounts, such as J. C. Arthur and A. G. Johnson's 1900 report, indicate that *U. maydis* caused hair to fall out and limbs to atrophy. These authors also cite earlier testimony that corn smut caused abortion in cows. Various reports attributed human respiratory ailments to corn smut, and in 1935 two Yugoslavian researchers identified a disease they called ustilaginism that was caused by corn smut poisoning.



The most detailed compilation, the 1957 volume *Biology and Control of the Smut Fungi,* by George William Fischer and Charles Stewart Holton, includes numerous anecdotal accounts of smut ingestion. F. J. Imhof in 1784, for example, consumed "a considerable quantity of the spores before breakfast every morning for a full two weeks. He also applied the spores to a wound on his hand and even had the originality to employ them as a snuff. No ill effects of any kind resulted from these experiments." In 1896, a farmer named Smith fed seven pounds of corn smut per day to his cows without ill effects. Reviewing all the evidence, Fischer and Holton concluded that the fungus's toxic effects on humans and animals were "not clear-cut and irrefutable and that considering the scientific experiments by themselves, the results of toxicity were predominantly negative."

Nevertheless, the absence of scientific studies on the short- or long-term health effects of *U. maydis* was disquieting. More mention of toxicity than of edibility was made in the technical literature. Disputes about edibility are, of course, not uncommon in mycophagy, where the same mushroom species can be described as edible in one field guide, of uncertain edibility in another, and toxic in a third. Some explanations for these differences are that the mushroom produces idiosyncratic responses in different people, that regional differences exist, or that different preparation methods have been used.

Can I recommend corn smut for popular consumption? I can vouch for its nonculinary aspects without qualification—its use as a darkening agent for skin and hair in China and Japan, for example, or as an art medium. I am, finally, reluctant to become an advocate of its use as food—despite a freezer full of *huitlacoche*—as too many unanswered questions remain. Needless to say, Mexican restaurants serve *huitlacoche* regularly, and it is marketed in canned form without reports of untoward effects. But like other mycophagists, I make a distinction between personal consumption of food items and recommending these same items to others under the mantle of authority.

Robert Sommer is professor of psychology and chair of the Department of Rhetoric and Communication at the University of California at Davis. His books include Farmers Markets of America, The Mind's Eye, *and* A Practical Guide to Behavioral Research.

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Sandia Cienega, New Mexico

by Robert H. Mohlenbrock

The rugged Sandia Mountains rise abruptly east of Albuquerque, New Mexico, extending from their 6,000-foot base to 10,678-foot Sandia Crest in just 2.7 miles and then tapering off somewhat more gradually. Because it faces the rays of the hot afternoon sun, the steep western side of the range is sparsely vegetated, with many bare patches of rock and sand. Many of the plants that grow there—gnarled piñon pines and Rocky Mountain junipers, cholla and prickly-pear cactuses, yuccas, agaves, bear grass, sagebrush, rabbitbrush, snakeweed, and stunted asters—are typical of the Chihuahuan Desert, whose main expanse is farther south. The eastern slopes, in contrast, are heavily forested with conifers. Driving along the scenic highway that snakes up the east side to Sandia Crest, one passes through several zones of vegetation, from semidesert at the lowest elevations to Hudsonian conifer forest at the crest.

Several springs and groundwater seeps emerge here and there on the eastern slopes, giving rise to unexpected wetlands in the midst of dense forests. Where standing water remains throughout the year, trees do not take hold, and the marshes that form may range in size from just a few square feet to several acres. In the western United States, such mountainside marshes are referred to as cienegas (from the Spanish *ciénaga*). The Sandia Cienega, about three acres in extent, is located on Forest Road 190, just a short detour off the route to Sandia Crest. It falls within Cibola National Forest, which has constructed a wheelchair-accessible trail along the cienega's east end. (Clumpy vegetation and standing water more than a foot deep can make walking hazardous, so visitors are encouraged to keep to the trail.)

At an elevation of about 7,600 feet, Sandia Cienega slopes very gently west to east. Two spring-fed rivulets form its northern and southern borders, while seepage from the bedrock creates areas of standing water throughout the year, particularly in the eastern and southern sections of the cienega.

Sandia Cienega is completely surrounded by forest. The rivulet on the northern edge is lined with box elder, bluestem willow, and New Mexico locust. The viny western virgin's-bower, or Rocky Mountain clematis, scrambles over some of these trees. The flowing water of the rivulet is home to the American brooklime, a small blue-flowered aquatic that belongs to the snapdragon family.

The gentle south-facing slope beyond the rivulet is forested with piñon pine, Rocky Mountain juniper, alligator juniper (with its square-plated bark that resembles the scaly back of an alligator), ponderosa pine, and Gambel oak. Beneath them grow several wildflowers, including blue beardtongue, scarlet beardtongue, white cress, rose geranium, and Mexican squawroot. The squawroot is a six-inch-tall, stubby plant that, lacking chlorophyll, survives by parasitizing the roots of pines and oaks. During the summer, yellowish flowers form in the axils of its dull-brown scale leaves.

A wild lettuce, above, offers its seeds to the wind. Opposite page: Helianthus blooms at the eastern end of Sandia Cienega.
Photographs by David A. Ponton

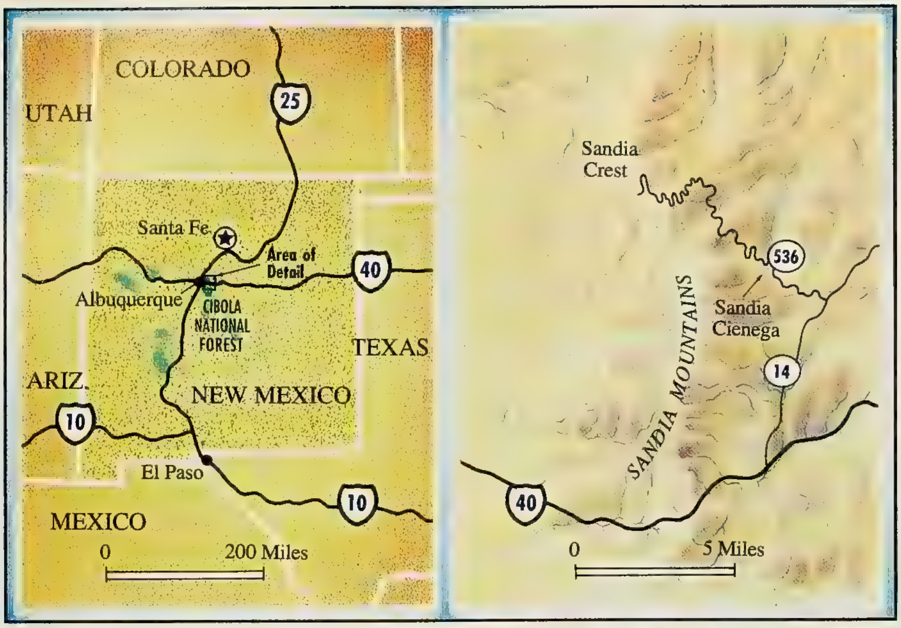
The north-facing slopes on the south side of the cienega are much more moist and are densely forested with white fir and Douglas fir. Understory plants include white baneberry, red columbine, larkspur, and mountain bluebells.

At the east end of the cienega, the wetland merges into hardwood forest that overlooks a picnic area. Similar woods appear on the west end, beyond the adjacent road. The hardwood trees are box elder, quaking aspen, and chokeberry, with hop tree the main component of the shrub layer. One of the common wildflowers is the starry Solomon's-seal. Because of the disturbance created by the presence of the trail, road, and picnic area, many weeds of European origin have invaded the eastern and western edges of the cienega. Two kinds of brome grasses, sow thistle, and prickly lettuce are common.

Where the cienega remains wet throughout the year but not inundated, the native species include a leafy aster with blue flower heads that open during the autumn, mountain avens with flowers bearing five yellow petals followed by spherical fruits that are soft and prickly, white rock cress, tall forget-me-not, fall-flowering mountain goldenrod, and golden glow. Golden glow is a five-foot-tall perennial that is related to black-eyed Susan except that it does not have the characteristic dark center of a black-eyed Susan and has deeply lobed leaves.

Toward the eastern end of the cienega, but extending westward along the north

Joe LeMonnier



Sandia Cienega

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and south sides, standing groundwater is ideal habitat for woolly sedge, small-fruited bulrush, flat-stemmed rush, smooth horsetail, bluejoint grass, canary grass, marsh manna grass, water bent grass, and marsh bluegrass. These are all native species that require wet soil and often standing water for at least a part of the year.

Nearly all the trees and wildflowers that live in the piñon-juniper forest and in the Douglas fir forest on the slopes near the cienega are restricted to the western United States. In contrast, most of the species that live in the cienega or the adjoining hardwood forest have a wider geographical distribution, with some found as far away as the Atlantic seacoast. Plants such as woolly sedge, bluejoint grass, marsh bluegrass, manna grass, smooth horsetail, canary grass, and American brooklime are found all across the northern half of the United States and into adjacent Canada.

This phenomenon—that plants living in wetlands generally have a broader geographical range than those living under drier conditions—can be observed throughout the country. One possible explanation is that the seeds of wetland plants are ingested by waterfowl or cling to the birds' feathers and muddy feet. Because of the great mobility of waterfowl species, the seeds are disseminated over a wide territory.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

Western virgin's-bower, whose fluffy seed heads appear in late summer, is a vine that grows over some of the trees lining the cienega's northern edge.
Robert McCaw

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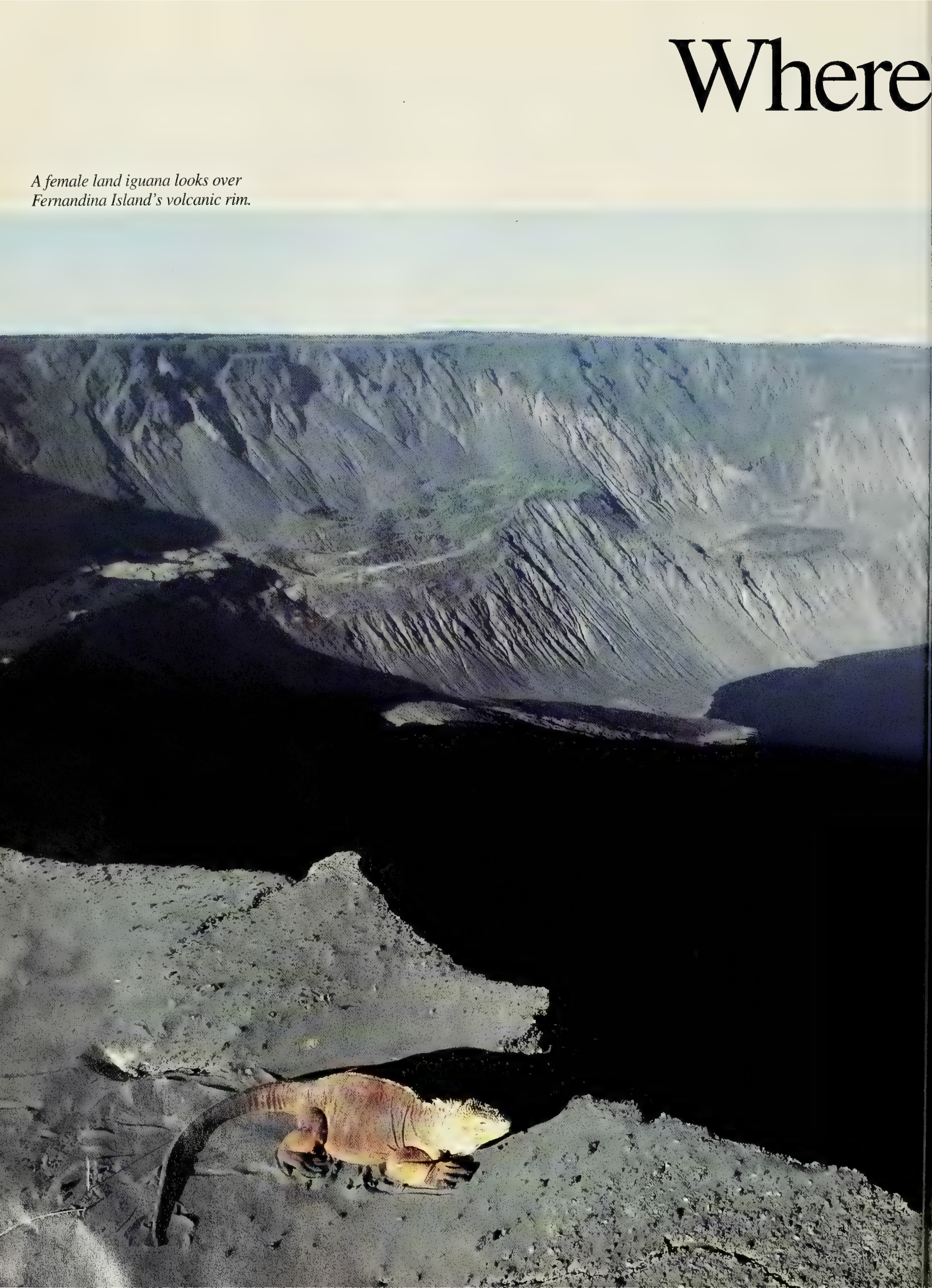
* False. The *Dimetrodon* was actually an early relative of mammals that lived in North America some 280 million years ago.

Where

A female land iguana looks over Fernandina Island's volcanic rim.



Vulcan Lizards Prosper

On a Galápagos island, female iguanas lay their eggs inside an active caldera

Text and photographs by Tui De Roy

Fernandina Island, the westernmost of the Galápagos group, remains one of the world's most pristine habitats. The circular, twenty-mile wide island is actually a young volcano, whose symmetrical dome rises almost 5,000 feet above the Pacific Ocean and encloses a gaping caldera almost four miles wide and nearly 3,300 feet deep. One of the world's most active volcanoes, Fernandina's major eruptions every few years rearrange much of the island's stark landscape. A visitor encounters marine iguanas, land iguanas, Darwin's finches, and a host of other species unique to the Galápagos that have survived in the midst of Fernandina's constant geophysical change. Charles Darwin, who visited the Galápagos a century and a half ago wrote of the archipelago that "both in space and time, we seem to be brought somewhat near to that great fact—that mystery of mysteries—the first appearance of new beings on this earth. . . . One is astonished at the amount of creative force, if such an expression may be used, displayed on these small, barren, and rocky islands."

I was raised in the Galápagos, on the central island of Santa Cruz, and first became interested in volcanoes when I was still a girl. Since my earliest childhood, my parents, who were amateur naturalists, had shared with me their inquisitiveness about our islands. On June 11, 1968, when I was fourteen, my family watched a large eruption on Fernandina, which was about eighty-five miles from our home. I vividly recall the huge columnar cloud of ash and steam rising high in the western sky and fanning into a mushroom shape. Powerful sonic booms and gigantic lightning bolts followed and continued throughout that evening. Some weeks later, I met volcanologist Tom Simkin, of the Smithsonian Institution, during his first trip to the islands. He interviewed me while gathering first-hand accounts of the eruption from local residents. Simkin later reported that the entire caldera floor had collapsed by almost one thousand feet, tremendously enlarging the space inside the dome. Infrasonic shocks from this eruption had regis-

A major 1978 eruption created billows of steam, right, as lava flowed into Fernandina's lake, extinguishing all aquatic life. Below: A volcanic vent spews molten rock inside the caldera, altering its landscape.

tered on seismic instruments throughout the Western Hemisphere with intensities comparable to those from a major nuclear explosion.

A couple of years later, I made my first visit to the rim of the volcano, which increased my fascination with the place. I began to go there more frequently, sometimes in my capacity as a professional wildlife photographer and several times as a collector of field data for Tom Simkin's volcanological team. As a resident volcano enthusiast, whenever I heard of another eruption at Fernandina, I would hurriedly mount another miniexpedition to investigate. Each visit involved a two-day boat trip and a long day's hike to the summit. Later, I would send Simkin my reports and rock samples.

I was also intrigued by the abundance and resilience of the island's wildlife and their adaptation to the frequent reshaping of their environment. When not riding thermal air currents, Galápagos hawks soared on the updrafts created by the massive rock avalanches that rumbled down the volcano's inner walls. Galápagos doves and Darwin's finches plunged blithely into gaping crevasses to drink the condensing water droplets from hissing fumaroles. And a huge population of land iguanas dotted the sparsely vegetated outer flanks of the volcano, where they dug spacious burrows in the blanket of volcanic ash left by the 1968 activity.

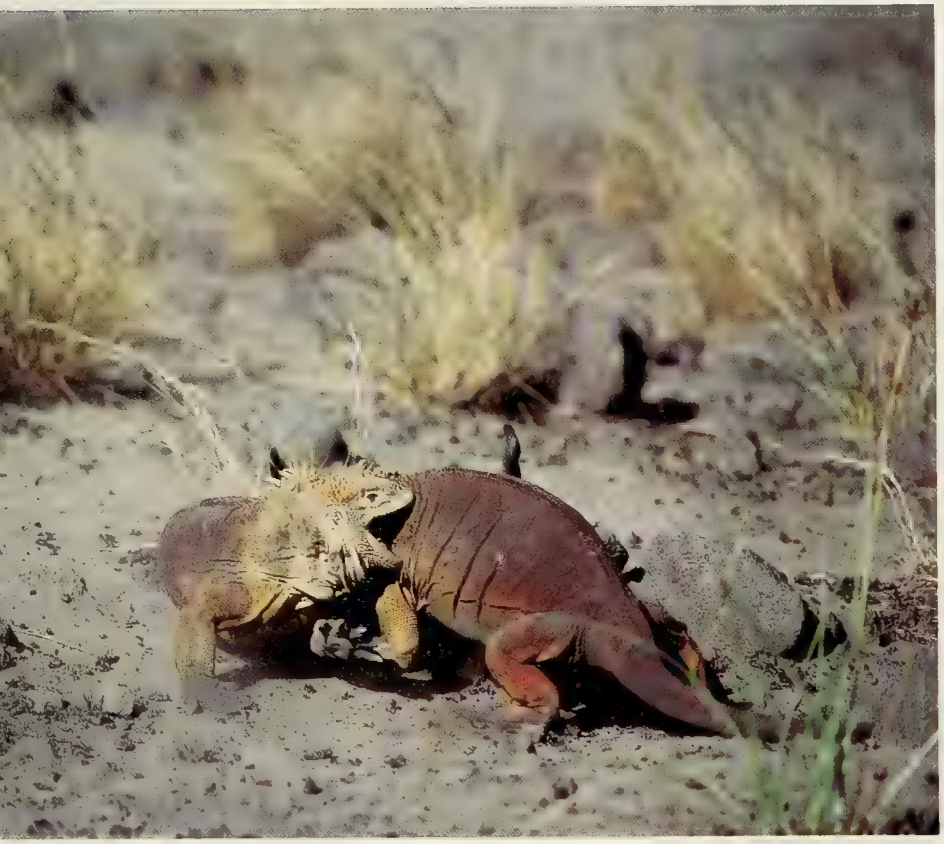
Although these reptiles live on five other Galápagos islands, Fernandina's land iguanas remain the only endemic population that has been relatively undisturbed by humans or by introduced animals. They are large lizards, with males generally weighing fifteen pounds and females about half that much. Although they occasionally eat insects, land iguanas are mostly herbivorous. Among the fifty species of plants they are known to eat, Fernandina's iguanas tend to concentrate on the buds, flowers, and leaves of wild morning glories, nightshade, berries, and endemic tomatoes, depending on seasonal availability.

During several subsequent visits to Fernandina, I tried to take in all the volcano's features—the steamy vents, the cinderlike lava, and the widely fluctuating fortunes of its bird populations. I was still unaware that the iguanas, so familiar to me from other islands, acted very differently here. Nothing was known at that time about their remarkable nesting habits.

On a July 1974 visit, I spotted my first clue. A large number of iguanas, mostly females, were pacing restlessly along the caldera edge, although I had no idea why. On a trip there the following month, my father made another, interesting find: several fresh iguana carcasses crushed by landslides *inside* the caldera. What, I wondered, were these lizards doing deep inside the volcano?

On a family expedition in June 1975, rather than remaining on the volcano rim as I had done before, I made my first descent into the caldera itself. That was a rather precarious enterprise because the walls were unstable, and the thick layer of 1968 ash was constantly eroding. When I reached the caldera floor, surrounded by soaring rock walls that were continually avalanching, I was struck by the dramatic contrast between the desolate moonscape and the thriving community of life. What supported this little ecosystem was a sizable lake, about 260 feet at its deepest point, so laden with mineral salts that it was unfit for human consumption. However, its rich microscopic algal soup supported myriad aquatic insects, which in turn fed some 250 white-cheeked pintail ducks—by far the largest population of these birds I had seen anywhere in the Galápagos. Although not a blade of grass grew inside the caldera, the air was

Near sparse clumps of grass on the caldera floor, below, two female land iguanas battle over a nesting site.



buzzing with dragonflies, while the shoreline was laced with the webs of various ground spiders, with lava lizards and indigenous snakes also in attendance. Less than two years earlier, a team of marine biologists had reported that during a brief eruption, a large lava flow from a caldera wall fissure had cascaded into the lake, boiling and killing all life within it.

What also caught my attention on that first descent were the abundant signs of land iguanas in the plantless expanses of volcanic ash. Although I saw only two or three lizards inside the volcano during my four-day stay, dozens of abandoned burrows dotted the flat pans and dry gullies, which contained many crisscrossed tail tracks. Etched in the rough, cindery bed of fragmented lava, or scoria, I even noticed clearly defined pathways, resembling game trails, that seemed to lead down from the volcano rim. Puzzled, I thought that the iguana population might have exploded during the brief rainy season, when some vegetation may have sprouted on the bare ash.

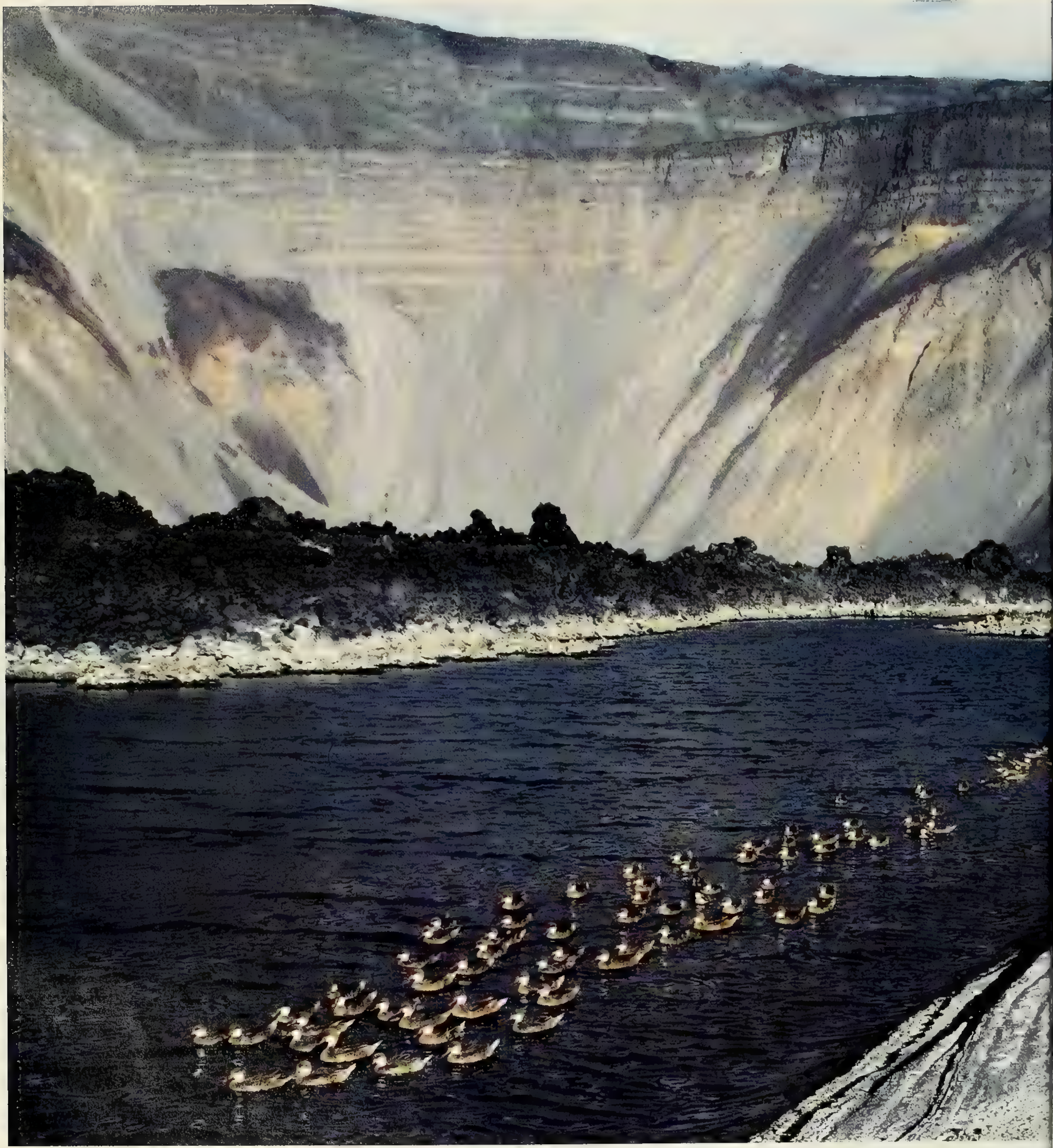
Twenty months later, I found myself inside the Fernandina caldera again as a part of a small team of researchers and volunteers collecting data and fresh lava samples from a new eruption. The molten rock had again poured into the lake, raising its temperature to near boiling. When I arrived, a week after the eruption, all aquatic life in the lake had been destroyed. The pintails, which had multiplied so spectacularly in the last few years, were sitting along the lake's steamy shoreline; with no insects to feed on, the birds were collapsing from starvation. With a sense of *dejà vu,* I noticed the signs of heavy iguana traffic and abandoned burrows, but had no better explanation for the mysterious movements than before.

The following year, 1978, I made two more visits to Fernandina; the first, to document another large eruption, was in August. The lava had flowed inward, cover-

After they bury their eggs, left, females guard them for several days, then climb out of the volcano. Several females, below, nest in a natural lava cave. On the caldera floor, bottom, another female buries her clutch of eggs.

ing much of the flat, stepped terrain where the iguana burrows and trails had been. Two months later, in October, I was back inside—this time with Tom Simkin and his group of volcanologists. I again found the mineral lake blue and lifeless. Still intrigued by the iguana signs I had seen on my previous visits, I searched for more clues, but this time found not even tracks. I settled for helping the volcanologists take temperatures and collect samples.

Four more years passed before I returned to the caldera floor, in October 1982. Despite a new, small eruption that had left deposits on the rim, the floor and the lake had been unaffected. The water was a rich pea soup color, and once again supported a flourishing population of pintails. Even more exciting, when I reached the lake shore I saw an unexpected sight. Dozens of Galápagos hawks were swooping down into the dry ravines, snatching up iguana hatchlings as they emerged from their nests. Although extremely wary



and well camouflaged, the tiny reptiles, only about eight inches in length, seemed to have little chance of escape, since they had no vegetation in which to hide. Dashing from the meager shelter of one boulder to the next, they seemed driven to reach higher ground, although they would have to travel several miles and climb 2,950 vertical feet before they would find any plant cover. Purely by chance, I had arrived when a major wave of iguana hatching was taking place. Probably the reason I had seen no hatchlings at all on my 1978 visit was because the lava flow had destroyed most of that year's eggs.

Finally, in July 1984, when I once more embarked on a rock-collecting expedition, a spectacular event occurred. Even while I was climbing the volcano's rim and outer flanks, I had noticed with growing excitement a large number of female iguanas, their abdomens swollen with eggs, trudging resolutely across the vast, sunbaked terrain. Dozens milled about the rim, many scrambling onto loose hanging boulders, which were often the first to give way in the daily avalanches. Now, from inside the caldera, I was able to observe and photograph a migration of hundreds of gravid iguana females scrambling down the volcano's inner walls. Shortly thereafter, I discovered their nesting grounds on the caldera floor.

In 1974, Fernandina's mineral lake, rich in algae and small organisms, supported a flock of white-cheeked pintail ducks, left. Four years later, after a major eruption, the lake was completely boiled away, leaving a deposit of dried sediment, below.

When I descended to the first flat areas where the steep walls leveled out into boulder-strewn steps, the scene was mind-boggling. A recent eruption had added lava that was still hot, yet wherever the underlying ash was exposed, female iguanas were digging, fighting, and searching for nest sites. Their activity was frenzied despite the intense heat caused by the cooling lava and the tropical sunlight focused within the bowl-shaped caldera. With many of the nests only one or two yards apart, dirt flung by one excavating female would land in another's burrow. Frequently, the large lizards gave open-mouthed, head-bobbing threat displays, occasionally culminating in aggressive chases. I watched one female pursue a rival with such vigor, riding on her back and biting her neck, that when the pair finally stopped some hundred feet away, the winner was unable to relocate her own unfinished nest. She spent the rest of the day checking every burrow entrance, incurring the wrath of its occupants in a vain search for her exposed eggs.

My fellow photographer and partner, Mark Jones, and I devoted the following day to gathering rock samples for the volcanologists, then decided to spend an extra day inside the uncomfortably hot caldera to continue watching the lizards jostle for nesting sites. To our amazement, when we returned to the same site we had observed two days earlier, virtually all the females had already deposited up to twenty-three eggs about two and a half inches long, and had refilled their burrows. Gaunt and skinny, with black ash caked around their eyes, their claws worn to stubs, and their abdomens wrinkled and shrunken, they vigilantly guarded their nests against any latecomers. The synchrony of the nesting surprised me nearly as much as the nesting itself. How could these reptiles from all over the island time their arrival so closely after walking great distances across

A Galápagos hawk, below, preys on an iguana on Santa Fe Island, east of Fernandina. Within the caldera, hawks prey mainly on hatchling lizards, not on adults. Right: Hot volcanic ash rained down on Fernandina's eastern rim in 1988, killing lush vegetation and burying many lizards alive. An iguana succumbed while trying to dig herself out.

scorching, jagged lava and descending the steep caldera walls?

During the period of my scattered observations, a definitive study of the biology of Fernandina's land iguanas was being conducted by a tireless German scientist, Dagmar Werner. In 1977, she set up a study site some three miles down the flank of the volcano and began tracking hundreds of lizards, including thirteen that she had fitted with radio collars. Amazingly, 95 percent of the females she observed migrated to the caldera to nest, a trip of up to nine miles, involving an initial climb of more than 3,000 feet, followed, in many cases, by an almost equal descent to the caldera floor. That is the longest distance known to be walked by any species of lizard to its nesting grounds. Werner's radio-collared animals walked relentlessly on cloudy days, over difficult terrain, pausing briefly every few minutes to rest. When the sun became intense they sought shade to prevent overheating and took between two and three days just to reach the rim. Werner told me of her frustration as the iguanas' radio signals were lost when the lizards descended the caldera. On average it took her study animals just over a month to complete this extraordinary round trip, with the eggs left to incubate, unattended, for three and a half months. The remaining 5 percent nested on the outer slopes of the volcano, especially around warm fumarole areas on the rim. In her published report, Werner included my observations of what took place inside the caldera.

To this day no detailed study of nesting behavior has been carried out inside the volcano or on the caldera floor. The difficulty in transporting supplies down the inner walls, the constant risk of landslides, and the absence of drinking water make it a daunting venture. Why do the iguanas invest such a disproportionate amount of

energy traveling to the heart of the volcano to lay their eggs? The losses to the iguana population—not only in energy expenditure but also in deaths from avalanches, destruction of nests and adult females by hot lava and ash, and hawk predation on young—are immense. Repeatedly in the last two decades, eruptions have taken place during the critical three and a half months between the early July egg laying and the October hatching, wiping out an entire season's reproductive effort.

Perhaps the temperature and dry climate inside the caldera, as opposed to the outer flanks of the volcano, are ideal for hatching the eggs. Indeed, the majority of those females that nest on the volcano's rim, where nighttime temperatures may drop almost to freezing, compete heavily for sites near high fumarolic activity, where the ground temperature remains above 86° F. But even so, land iguanas on other Galápagos islands succeed in nesting near the humid coasts.

How might these unique nesting migrations have become established? Perhaps Fernandina underwent a prolonged lull in volcanic activity that lasted several thousand years and ended only in recent times. With the dense vegetation that prevailed at higher elevations (still largely evident until the 1968 eruption), the warmer, drier regions of the sleeping volcano would

During a rare social gathering, Fernandina's land iguanas bask together in the afternoon sun.

have been the best places on the island for nesting, since the rocky coasts lacked soft sand. Because iguanas, like some other reptiles, may return to nest in the same area where they were hatched, the migration pattern might have become established during this long, dormant period. (Only a series of core samples can establish whether this is a plausible scenario.) In recent centuries, however, the high level of volcanic activity seems to have made the migrations somewhat dysfunctional. Future generations of iguanas may eventually be forced to abandon the caldera in favor of less precarious nesting sites. No one knows, however, how long it might take for such behavior to change.

The most recent eruption of Fernandina was in September 1988. Without warning, a blanket of scorching cinder and rocks covered a large area on the rim of the volcano, stripping foliage and bark off trees and baking many iguanas to death. At the same time, a huge segment of the rim collapsed, followed by a lava flow that disfigured the caldera beyond recognition. The lake was completely buried and the entire floor covered by an enormous layer of rubble, just a few weeks before the main iguana hatching period. When I joined a geology team a year later, nothing on the caldera floor bore the slightest resemblance to what I had seen in the past. The only reminder of former days came at the lowest point of the caldera floor where one of two tiny ponds flourishing with algae held one lone pintail.

Yet as I walked this eerie, pock-marked landscape plastered with baked lake sediment, signs of iguanas were everywhere, and the latest wave of hatchlings was already emerging. This delicate interplay between island life and volcanic forces brought to mind the other great Fernandina mystery: a race of large saddleback tortoises that is known from only a single specimen collected on the island in 1906. Apparently, this species became extinct less than a century ago entirely because of natural conditions on Fernandina. So far the indomitable land iguana has escaped such a fate. □

Dinosaurs and Drifting Continents

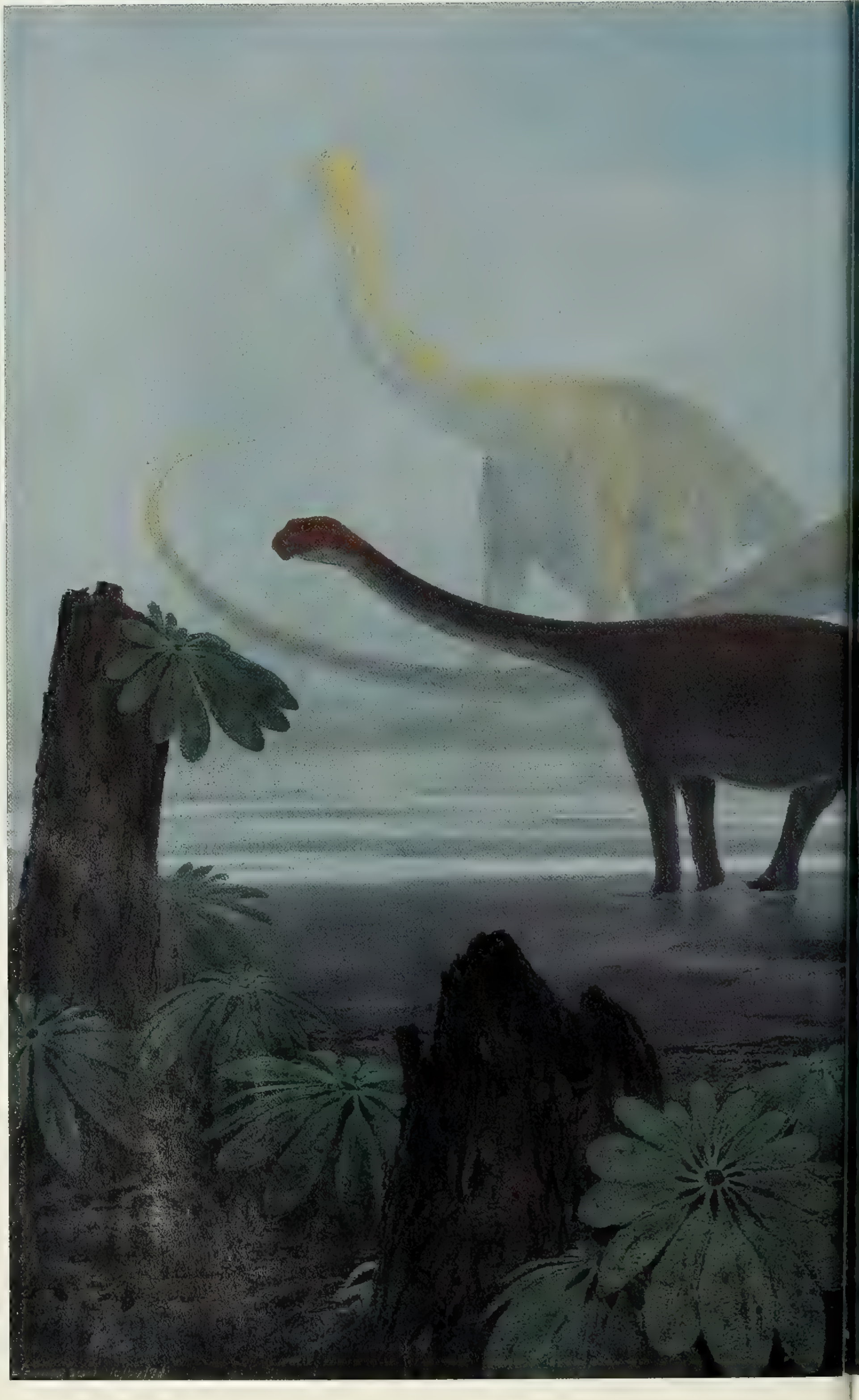
New fossil finds in the Sahara reveal how evolution goes with the global flow

Paul C. Sereno

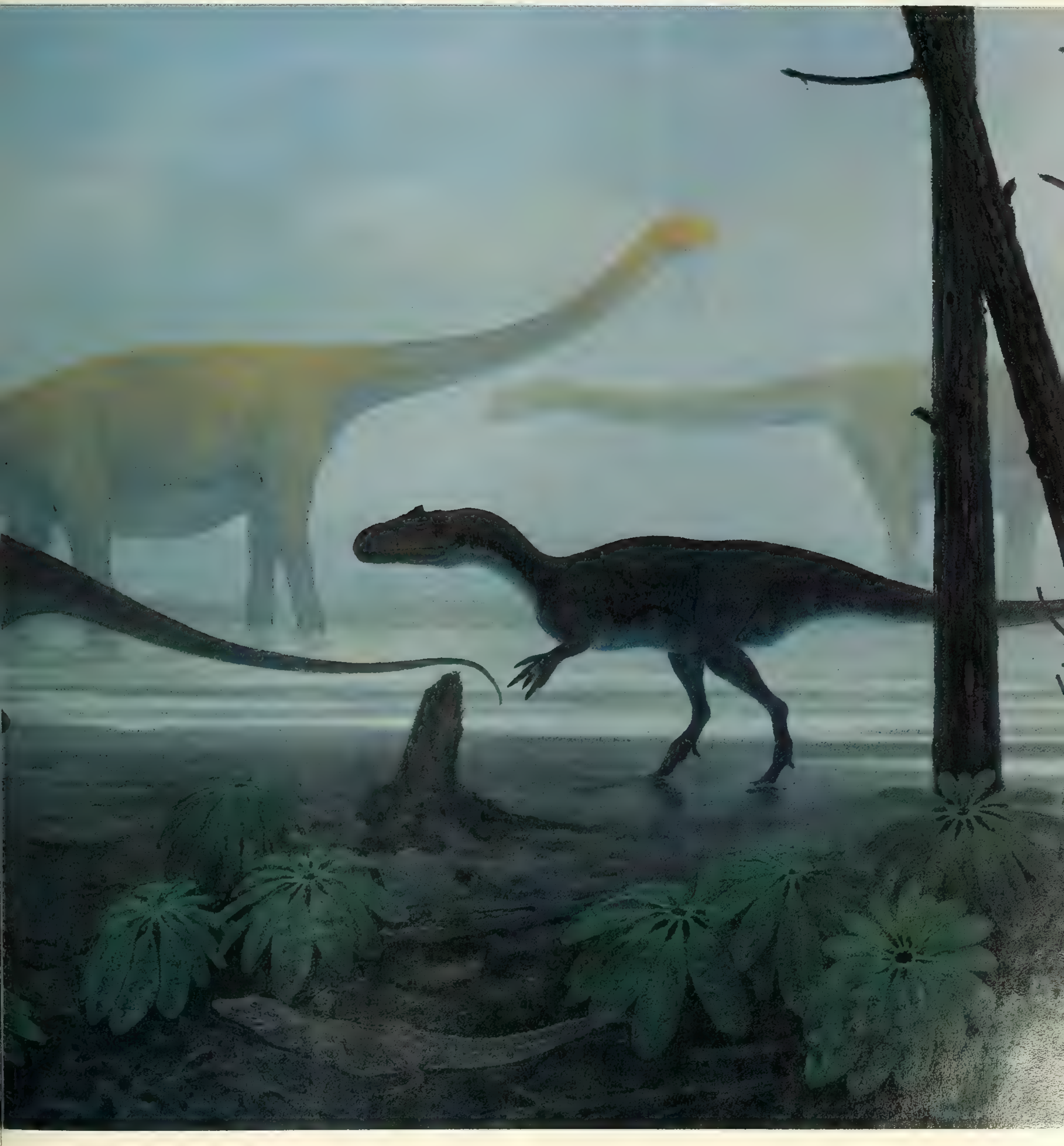
As I waited in a small hotel in the 100-plus degree heat in Niamey, the capital of Niger, the expedition team I had assembled languished in the Saharan oasis town of Agadez, some six hundred miles to the north. Equipped with six Land-Rovers and more than a ton of dehydrated food and other provisions, the team had withstood a grueling 2,000-mile desert crossing in order to hunt for dinosaur fossils. But permission to explore the remote desert areas had been stalled for weeks in the ministries in Niamey. Two years prior to our arrival, the area had been engulfed in political turmoil, and since then banditry had become commonplace. With each passing day, isolation and uncertainty more deeply eroded the confidence of the crew in Agadez. Some had decided to head home early, and one was seriously ill; an unprecedented strike had brought air traffic to a standstill, preventing the arrival of cash needed to continue the expedition; and the document that would guarantee access to the field had yet to materialize. The whole venture now looked like a meticulously planned disaster. Under intense pressure, I left for Agadez in a packed "bush" taxi, to cancel the expedition that I had spent three years planning.

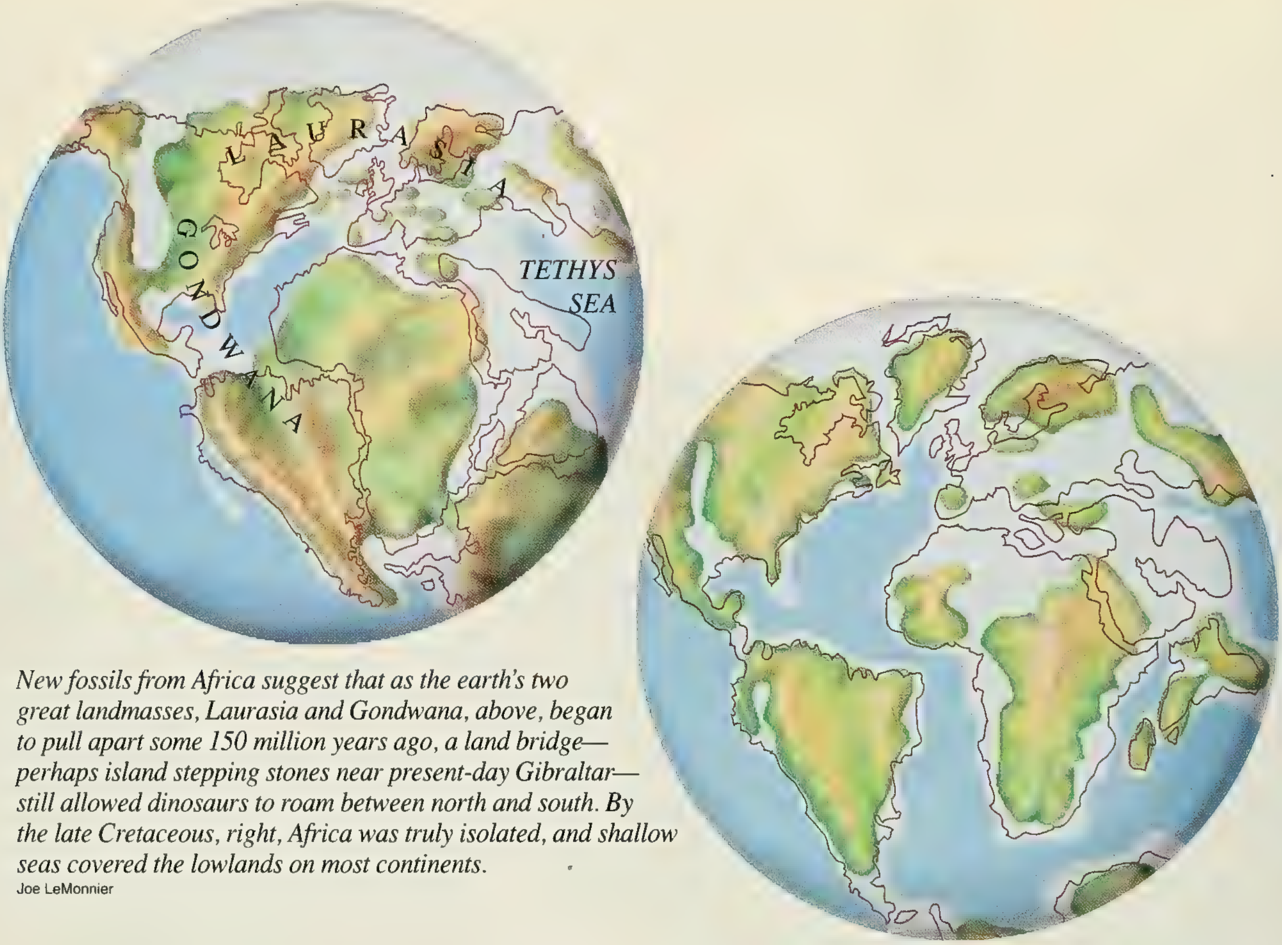
The current expedition had its origins three years earlier, when I joined a British Museum trip to Niger. Their party was interested in fossil fish, and my interest was in dinosaurs. My objective was to explore Cretaceous beds, estimated to be 130 million years old, that were exposed in a broad swath across the northern part of the country. Discovery of dinosaur skeletons in African rocks of this age could lead to a better understanding of dinosaur biogeography and, in particular, how geographical isolation influenced the late phase of dinosaur evolution on the continent of Africa.

Toward the end of the Jurassic, some 150 million years ago, the earth's landmasses, which earlier had coalesced to form the supercontinent of Pangaea, began to fragment. Gradually, the shifting



Long-necked sauropods linger at a stream, unaware that the thirty-foot-long predator Afrovenator *(right foreground) is eyeing the youngster in their group (left). This reconstruction is based on fossil sites in Niger, along the southern edge of the Sahara Desert.*
Painting by Doug Henderson





New fossils from Africa suggest that as the earth's two great landmasses, Laurasia and Gondwana, above, began to pull apart some 150 million years ago, a land bridge—perhaps island stepping stones near present-day Gibraltar—still allowed dinosaurs to roam between north and south. By the late Cretaceous, right, Africa was truly isolated, and shallow seas covered the lowlands on most continents.

Joe LeMonnier

of the earth's plates pulled the northern landmass, Laurasia, and the southern, known as Gondwana, apart. Then, at the beginning of the Cretaceous, about 20 million years later, further movements of crustal plates began to separate what are now the continents of Africa, South America, Antarctica, and Australia. The African continent—and its creatures—entered a long period of isolation.

Just how dinosaurs responded to these gradual but profound changes in their world is not known in detail, but we suspect that as the continents became increasingly isolated, dinosaur faunas in different geographical areas became more differentiated. Many dinosaur subgroups from this period are found in only one part of the world. Predators like *Tyrannosaurus,* for example, are known only from western North America and central Asia. Their contemporaries, the horned dinosaurs such as *Triceratops,* are even more localized, having been uncovered only in western North America.

While paleontologists have learned much about Cretaceous life in the Northern Hemisphere, comparatively little is known about dinosaurs from this period on the southern continents. The best record comes from the Patagonian badlands of South America. This area has yielded large predators such as *Carnotaurus,* a bipedal meat eater that belongs to a group known as abelisaurs and is characterized by blunt forehead horns. South American Cretaceous herbivores were also different from their northern counterparts. On the northern landmasses during the Cretaceous, sauropods—the huge, long-necked, quadrupedal plant eaters—had largely given way to ornithischians, such as the horned and duck-billed dinosaurs and the tanklike ankylosaurs. In South America, however, almost all of the Cretaceous herbivores belong to a distinctive group of sauropods known as titanosaurs, which are characterized by their narrow, cylindrical teeth. One recent hypothesis suggests that a similar abelisaur-titanosaur fauna extended across all of Gondwana prior to the breakup of South America and Africa. The scarcity of fossils from other southern continents, however, leaves room for other scenarios.

This thought was on my mind on the day in 1990 that I and my British colleagues stumbled upon a vast graveyard of dinosaur skeletons, the bones poking above the desert plain. A crucial piece of the biogeographical puzzle lay there half buried, and I was consumed with plans for a return expedition.

Now, however, as I led the team back to Niamey and wondered how I would dismantle the expedition and get everyone out of Africa, the romance and challenge of the Sahara seemed very remote. Just then our fortunes turned. The bedridden team member regained his strength, the cash arrived in the hand of a friend, and the elusive final document authorizing our fieldwork finally materialized. The expedition began to breathe new life. Yet about half the team regarded the reborn mission, which included a military escort while in the field, as risky and rushed, and they headed for the airport.

Now a streamlined team of ten, we drove north into the desert. We had less than one month to relocate the skeletons found three years ago, prospect new sites, map and excavate what might amount to tons of fossil bones, and somehow transport this load across the world's largest desert to Algiers, where our transport ferry was scheduled to pick us up.

We set up headquarters in the oasis town of In Gall. Drawing on my memory of the landscape, some faded Polaroid

A campsite in the open desert of southern Algeria was one of many stops in the expedition's 2,000-mile trek across the Sahara to the fossil beds in Niger.
Eric DeBolt

shots, and the knowledge of a local guide, we soon found the graveyard from 1990, and with a subset of the crew set out to explore the surrounding desert. On our second day out, we stopped the Land-Rover to get our bearings and spotted a large bone about fifty yards away. It was a five-foot-long humerus, one of the forelimb bones of a sauropod. The elbow joint was just visible, and after a few minutes of spirited digging, we determined that more of the forelimb was below the surface. The following day, part of the team began to excavate the sauropod arm, while the rest of us, accompanied by a Tuareg nomad, drove to a distant butte. Here we found fossil bone fragments scattered in many places. I recognized one of the larger fragments as the hip bone of a theropod, a bipedal carnivorous dinosaur. I was breathless as I thought of the significance of finding Africa's first theropod skeleton from the Cretaceous, and I scanned the surrounding surface clay for any other traces of the beast. Nearby were several bones from the hind limb and, most exciting, a small claw from the hind foot.

The fourth day of prospecting brought to light a second theropod site and a few more sauropod remains, more material than we could excavate in our remaining time. First, we turned our attention to the sauropod forelimb. Those bones led to a hind limb, which led to a pelvis, ribs, and a long tail. We followed the enormous skeleton into the ground, carving a gaping hole around it. On the wall of this hole, we discovered a sharp break in the color of the sediments. A dark brown layer represented the floor of an ancient river into which the sauropod had fallen. By taking measurements down to this layer around the skeleton, we touched the bottom and sides of a giant trough. Most of the right side of the skeleton had become mired in mud near the bottom of this channel, whereas the bones on the left side had been washed away by river currents. The river sediments also yielded evidence of other creatures that had shared the sauropod's habitat; we found bones, teeth, and scales of predatory dinosaurs, crocodiles, turtles, and fish. In all, we excavated five tons of fossil bones in just under two weeks before turning our attention to the first theropod site.

The remains of the theropod and the circumstances of its death were more difficult to assess. The few bones that were exposed on the surface were not articulated, or connected to one another. But as we brushed back the sediment, we eventually excavated many vertebrae, sickle-shaped hand claws, numerous hand and foot bones, and the bones of a long skull with two-inch, blade-shaped teeth. These remains lay inches above the floor of an ancient riverbed in rock stained purple and blue. Sauropod bones near the theropod

skeleton indicate that these two animals lived in the same habitat: one, the predator; the other, the prey.

Fossil conifer wood near the theropod site showed no evidence of tree rings, suggesting that the ancient climate was not marked by strong seasons or by periods of drought. Our geologic samples indicated the existence of ancient soils and shallow lakes. Not only the climate but also the geographical position of this and our other sites had changed since these bones were buried. Carried by moving plates, Africa had drifted east and north. Whereas today the bones are situated in a desert some seventeen degrees north of the equator, 130 million years ago, the African dinosaurs we had discovered lived within five degrees of the equator in a stable, warm environment with stands of conifers, shallow lakes, and rivers.

We returned to the original graveyard and outlined two of the skeletons. The proportions of the bones matched those of the sauropod we had just unearthed, and we grew more confident that we had found several individuals of the same species. We had no time to collect the bones but were able to get an impression of the arrangement of the skeletons and the circumstances of their burial. These animals seem to have been swept into a river and buried quickly by channel muds more than five feet thick. The high angle at which the largest bones were tilted suggested that the sauropods in this graveyard had been buried instantly, as might happen if they had been caught in a flash flood.

With a metal tripod rented from an oasis mechanic, we lifted the skeletal blocks and slid them into a desert-worthy truck that we had arranged to meet us on our last day in the field. We left In Gall and headed north, working our way across the desert, over the Atlas Mountains, and down to the port city of Algiers, where we loaded the vehicles and our six tons of fossils onto the ferry. Taken to Paris by rail from the ferry

Team members Gabrielle Lyon, Didier Dutheil, and Jeffrey Wilson, left, painstakingly brush sediment from the remains of what proved to be a new species of carnivorous dinosaur. Below: Two varieties of desert transport pass at the foot of the Grand Erg Occidental, an immense dune field in eastern Niger.
Photographs by Paul Sereno

landing in Marseille, the bones were then airlifted from Paris to Chicago, and finally transported by truck to the Royal Ontario Museum in Toronto for cleaning. As they emerged from their plaster jackets one by one, we were able to scrutinize our new bones and compare them with other specimens. How would the first reasonably complete dinosaur skeletons from the Cretaceous of Africa fit into the global scheme of dinosaur evolution?

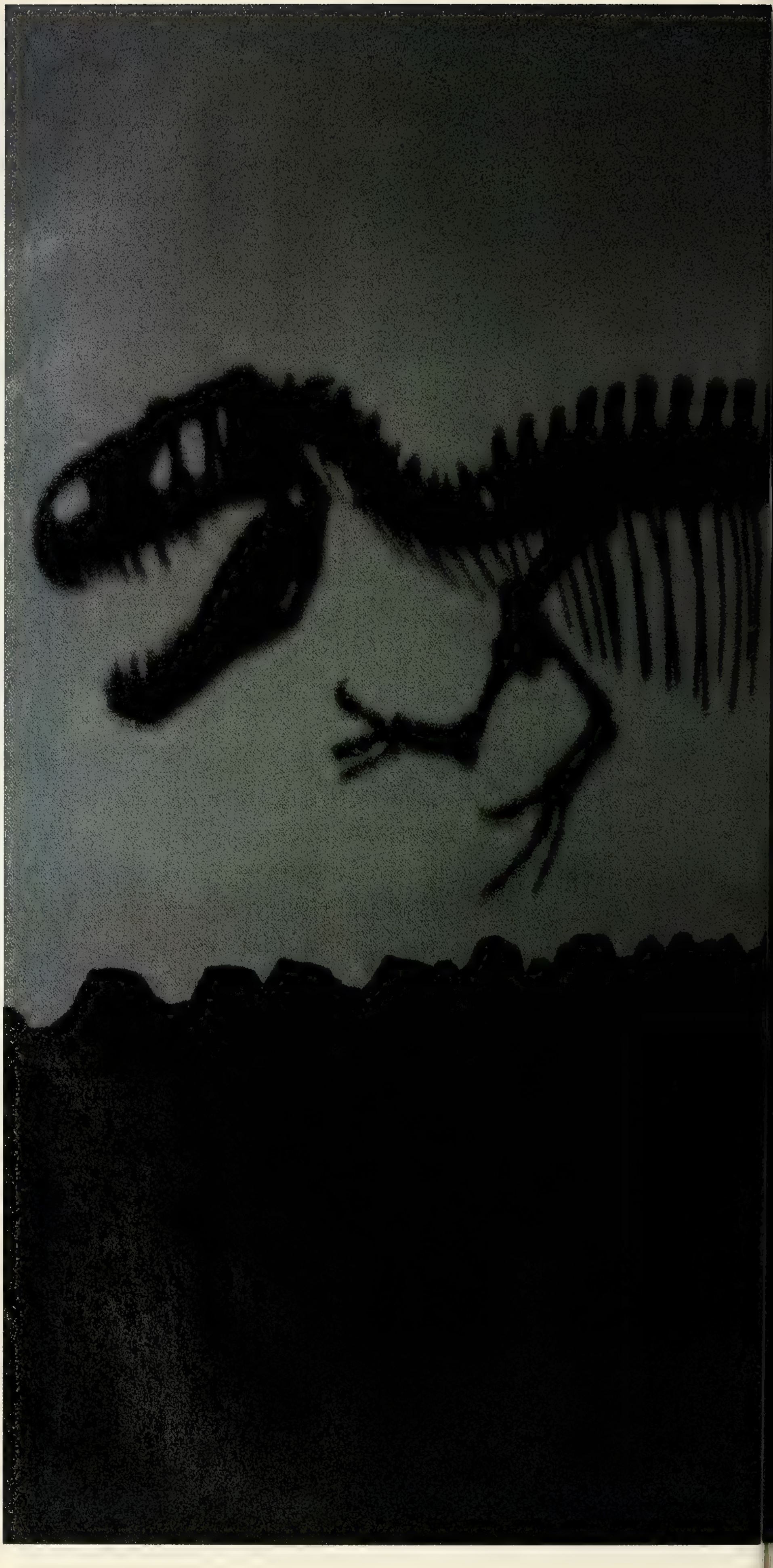
The sauropod did not support the idea that similar dinosaurs had inhabited all of Gondwana during the Cretaceous. Our beast clearly was not a titanosaur, the sauropod group common at this time in South America. The jaw we had collected contained broad, spatulate-crowned teeth, similar to those of *Camarasaurus,* a late Jurassic sauropod from western North America. These sauropods left little or no trace on other continents during the Cretaceous. Our discovery suggests that a lineage of these broad-toothed sauropods survived into this period in Africa.

Similarly, the long skull of our theropod bore no resemblance to South American abelisaurs, but had much in common with the skull of *Allosaurus,* a species that thrived in late Jurassic times in western North America. The forelimbs were powerfully built with three-fingered hands that bore strongly recurved claws, and the long tail was stiffened by overlapping, bony struts. We named this new, thirty-foot-long predator *Afrovenator,* or "African hunter."

The evolutionary link between the new African dinosaurs and more ancient species to the north was puzzling. One possibility is that this link reflects a geographical connection between Africa and the north, a connection that was severed by plate movements during the Cretaceous. Prior to this time, dinosaurs from distant parts of the globe were quite similar. Late Jurassic dinosaurs from the north, for example, were much like those from contemporary deposits in eastern Africa. Thus a land bridge between Europe and Gondwana, near present-day Gibraltar, must have existed at that time, despite the growth nearby of formidable oceanic barriers. This land connection between north and south may have been severed at about the same time as the southern continents themselves were pulling apart. We concluded that before the breakup of Gondwana, there must not have been a significant interval of time during which Gondwana was truly isolated, with no dinosaurian traffic to and from the north. By the mid-Cretaceous, some 15 million years later, many dinosaur groups that were able to maintain a cosmopolitan distribution in the Jurassic and early Cretaceous found themselves isolated on island continents.

Once the continents were isolated, their dinosaur faunas diverged, each shaped by extinctions and evolutionary forces particular to its geographical areas. Thus in the north, sauropods waned and eventually died out as the dominant herbivores, and duck-billed and horned dinosaurs evolved into many different species and took their place as the main plant eaters. Theropods flourished with the evolution of the line leading to immense predators such as *Tyrannosaurus* and smaller but deadly carnivores like *Deinonychus.* In South America, in contrast, sauropods, both nar-

The mounted skeleton of Afrovenator, *or "African hunter," the first, near-complete predatory dinosaur to be found from the Cretaceous of Africa, displays the dynamic pose of a swift, bipedal carnivore.*
Hans Larsson



row-toothed titanosaurs and pencil-toothed forms known as diplodocids, became the dominant herbivores. Abelisaurs were the dominant large meat eaters. In Africa, the scenario seems to have been still different. Broad-toothed and narrow-toothed sauropods shared the role of large herbivores with ornithischians, while among carnivores, an allosaur-like lineage seems to have persisted in Africa throughout the Cretaceous. *Afrovenator* was among the first of this carnivorous lineage, which was later represented by the enigmatic spinosaurs, large predators with tall back spines, known from fragmentary fossils found in Morocco and Egypt.

The biogeographical complexity that arose toward the end of the age of dinosaurs may tell us something about how evolution works on a grand scale. The particular succession of dinosaurs during the Cretaceous in western North America—with duck-billed and horned dinosaurs replacing the elephantine sauropods, and with tyrannosaurs succeeding the allosaurs—may not be easily explained as the ascendance of dinosaurs of superior design. Were duck-billed and horned dinosaurs somehow better than sauropods at consuming plants? Was *Tyrannosaurus* the best-designed large predator of the Mesozoic? On landmasses such as South America, ornithischians made no such headway against sauropods. Likewise, the tyrant king is clearly only one possible outcome of theropod evolution on one landmass. The line that led to *Tyrannosaurus* in the north has yet to be recorded from Africa, whereas other, very different large theropods, such as *Afrovenator* and the spinosaurs, evolved.

The new African dinosaurs do support the view that dinosaur evolution was influenced by global geographical events. A study of dinosaurs on island continents also leads to a deeper appreciation of evolution as an interplay between large-scale geographical and climatic events and sheer chance. The outcome may be no more predictable than that of a well-planned paleontological expedition. □

To Catch a Colobus

Chimpanzees in Gombe National Park band together to kill nearly a fifth of the red colobus monkeys in their range

by Craig B. Stanford

On a sunny July morning, I am sitting on the bank of Kakombe Stream in Gombe National Park, Tanzania. Forty feet above my head, scattered through large fig trees, is a group of red colobus monkeys. This is J group, whose twenty-five members I have come to know as individuals during several seasons of fieldwork. Gombe red colobus are large, long-tailed monkeys, with males sometimes weighing more than twenty pounds. Both sexes have a crown of red hair, a gray back, and buff underparts. The highlight of this particular morning has been the sighting of a new infant, born sometime in the previous two days. As the group feeds noisily on fruit and leaves overhead, I mull over the options for possible names for the infant.

While I watch the colobus monkeys, my attention is caught by the loud and excited pant-hoots of a party of chimpanzees farther down the valley. I judge the group to be of considerable size and traveling in my direction. As the calls come closer, the colobus males begin to give high-pitched alarm calls, and mothers gather up their infants and climb higher into the tree crowns.

A moment later, a wild chorus of pant-hoots erupts just behind me, followed by a cacophony of colobus alarm calls, and it is obvious to both J group and to me that the chimps have arrived. The male chimps immediately climb up to the higher limbs of the tall albizia tree into which most of the colobus group have retreated. Colobus females and their offspring huddle high in the crown, while a phalanx of five adult males descends to meet the advancing ranks of four adult male chimpanzees, led by seventeen-year-old, 115-pound Frodo. Frodo is the most accomplished hunter of colobus monkeys at Gombe and the only one willing to take on several colobus males simultaneously in order to catch his prey. The other hunters keep their distance while Frodo first scans the group of monkeys, then advances upon the colobus defenders. Time and again he lunges at the colobus males, attempting to race past them and into the cluster of terrified fe-

A chimpanzee reaches out in pursuit of a red colobus monkey. Red colobus males vigorously defend the members of their group from such attacks, but the apes, which are much larger, are likely to succeed, especially if enough males hunt together.

Craig B. Stanford

Gerry Ellis, Nature Photography

Gombe chimps spend much of the day traveling in search of plant foods, below. If they encounter small antelopes, bush pigs, or colobus monkeys, however, the apes often decide to hunt. The preferred catch is baby colobus. Right: During a hunt of red colobus, some chimps may wait below, in a good position to catch any monkey that falls to the ground.

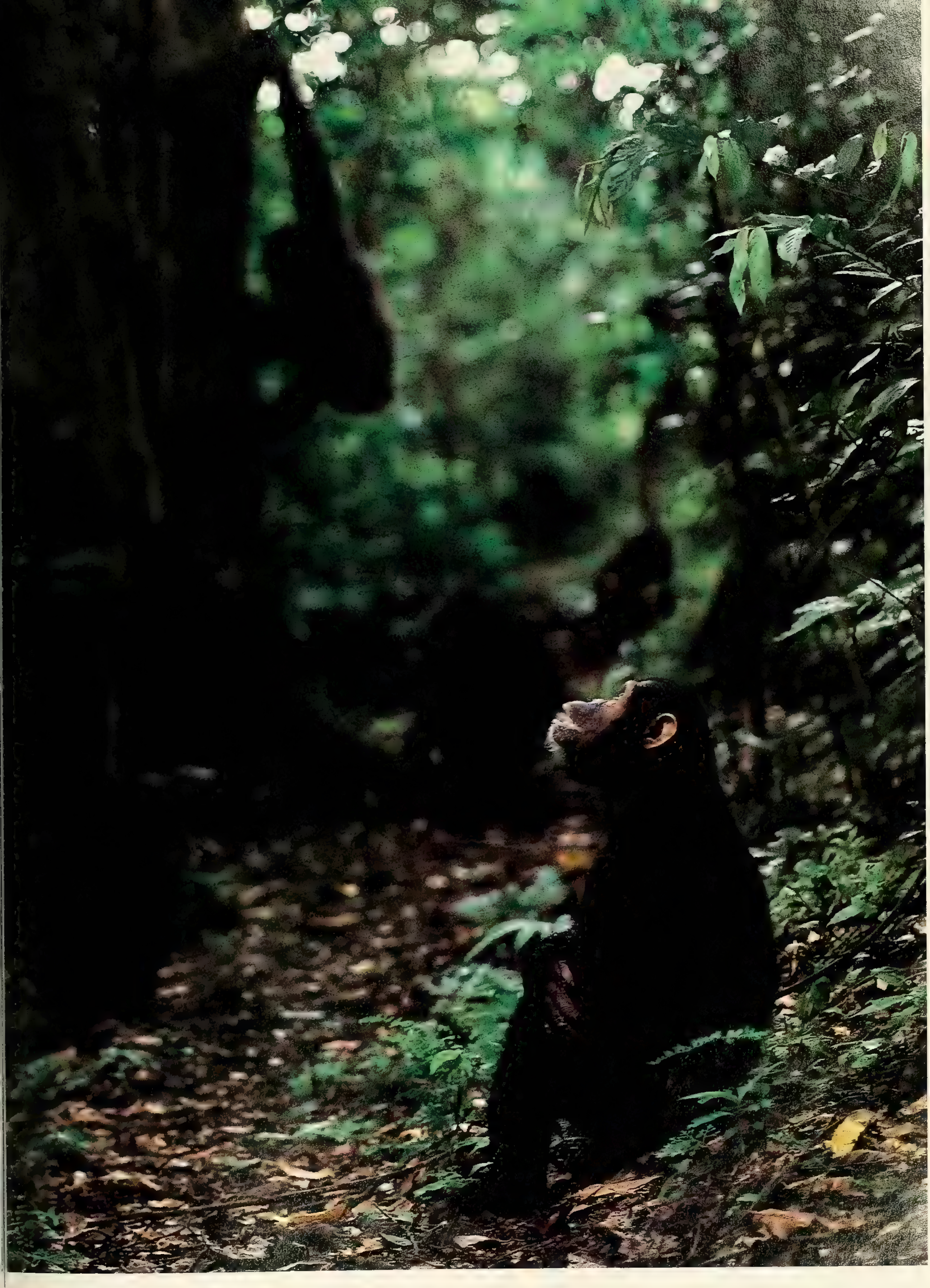
Kennan Ward

males and infants. Each time he is driven back; at one point, the two largest males of J group leap onto Frodo's back until he retreats, screaming, a few yards away.

A brief lull in the hunt follows, during which the colobus males run to one another and embrace for reassurance, then part to renew their defense. Frodo soon charges again into the midst of the colobus males, and this time manages to scatter them long enough to pluck the newborn from its mother's abdomen. In spite of fierce opposition, Frodo has caught his quarry, and he now sits calmly and eats it while the other hunters and two female chimps—their swollen pink rumps a sign that they are in estrus, a period of sexual receptivity—sit nearby begging for meat. The surviving colobus monkeys watch nervously from a few feet away. Minutes later, the mother of the dead infant attempts to approach, perhaps to try to rescue her nearly consumed offspring. She is chased, falls from the tree to the forest floor, and is pounced upon and killed by juvenile chimpanzees that have been watching the hunt from below. Seconds later, before these would-be hunters have had a chance to begin their meal, Wilkie, the chimpanzee group's dominant male, races down the tree and steals the carcass from them. He shows off his prize by charging across the forest floor, dead colobus in hand, and then, amid a frenzy of chimps eager for a morsel, he sits down to share the meat with his ally Prof and two females from the hunting party.

Until Jane Goodall observed chimpanzees eating meat in the early 1960s, they were thought to be complete vegetarians. We now know that a small but regular portion of the diet of wild chimps consists of the meat of such mammals as bush pigs, small antelopes, and a variety of monkey species. For example, chimpanzees in the Mahale Mountains of Tanzania, the Taï forest of Ivory Coast, and in Gombe all regularly hunt red colobus monkeys. Documenting the effect of such predation on wild primate populations, however, is extremely difficult because predators—whether chimps, leopards, or eagles—are generally too shy to hunt in the presence of people. The result is that even if predation is a regular occurrence, researchers are not likely to see it, let alone study it systematically.

Gombe is one of the few primate study sites where both predators and their prey have been habituated to human observers, making it possible to witness hunts. I have spent the past four field seasons at Gombe, studying the predator–prey relationship between the 45-member Kasakela chimpanzee community and the 500 red colobus monkeys that share the same twelve square miles of Gombe National Park. Gombe's rugged terrain is composed of steep slopes of open woodland, rising above stream valleys lush with riverine forest. The chimpanzees roam across these hills in territorial communities, which divide up each day into foraging parties of from one to forty animals. So far, I have clocked in more than a thousand hours with red colobus monkeys and have regularly followed the chimps on their daily rounds, observing some 150 encounters between the monkeys and chimps and more than 75 hunts. My records, together with those of my colleagues, show that the Gombe chimps may kill more than 100 red colobus each year, or nearly one-fifth of the colobus inhabiting their range. Most of the victims are immature monkeys under two years old. Also invaluable have



been the data gathered daily on the chimps for the past two decades by a team of Tanzanian research assistants.

One odd outcome of my work has been that I am in the unique position of knowing both the hunters and their victims as individuals, which makes my research intriguing but a bit heart wrenching. In October 1992, for example, a party of thirty-three chimpanzees encountered my main study group, J, in upper Kakombe valley. The result was devastating from the monkeys' viewpoint. During the hour-long hunt, seven were killed; three were caught and torn apart right in front of me. Nearly four hours later, the hunters were still sharing and eating the meat they had caught, while I sat staring in disbelief at the remains of many of my study subjects.

Determined to learn more about the chimp–colobus relationship, however, I continued watching, that day and many others like it. I will need several more field seasons before I can measure the full impact of chimpanzee hunting on the Gombe red colobus, but several facts about hunting and its effects on the monkeys have already emerged. One major factor that determines the outcome of a hunt in Gombe is the number of male chimps involved. (Although females also hunt, the males are responsible for more than 90 percent of all colobus kills.) Red colobus males launch a courageous counterattack in response to their chimpanzee predators, but their ability to defend their group is directly proportional to the number of attackers and does not seem to be related to the number of defenders. The outcome of a hunt is thus almost always in the hands of the chimps, and in most instances, the best the monkeys can hope to do is limit the damage to a single group member rather than several. Chimpanzees have a highly fluid social grouping pattern in which males tend to travel together while females travel alone with their infants. At times, however, twenty or more male and female chimpanzees forage together. When ten or more male chimps hunt together, they are successful nine times out of ten, and the colobus have little hope of escape.

Hunting success depends on other factors as well. Unlike the shy red-tailed and blue monkeys with which they share the forest (and which are rarely hunted by the chimps), red colobus do not flee the moment they hear or see chimps approaching. Instead, the red colobus give alarm calls and adopt a vigilant wait-and-see strategy, with males positioned nearest the potential attackers. The alarm calls increase in frequency and intensity as the chimpanzees draw closer and cease only when the chimps are sighted beneath the tree. Then, the colobus sit quietly, watching intently,

Despite its agility in the treetops, left, at least one individual in a group of fleeing red colobus monkeys is likely to be caught. In Gombe, successful chimp hunters are often approached by others in the group, hoping for a share of the prize, below. Pieces of meat are doled out strategically, mostly to allies, relatives, and sexually receptive females.

Photographs by Craig B. Stanford

and only if the chimps decide to hunt do the colobus males launch a counterattack. The monkeys' decision to stand and fight rather than flee may seem maladaptive given their low rate of successful defense. I observed, however, that when the monkeys scatter or try to flee, the chimps nearly always pursue and catch one or more of them.

Fleeing red colobus monkeys are most likely to be caught when they have been feeding on the tasty new leaves of the tallest trees, the "emergents," which rise above the canopy. When these trees are surrounded by low plant growth, they frequently become death traps because the only way colobus can escape from attacking chimps is to leap out of the tree—often into the waiting arms of more chimpanzees on the ground below.

One of my primary goals has been to learn why a party of chimps will eagerly hunt a colobus group one day while ignoring the same group under seemingly identical circumstances on another. One determinant is the number of males in the chimp party: the more males, the more likely the group will hunt. Hunts are also undertaken mainly when a mother colobus carrying a small infant is visible, probably because of the Gombe chimps' preference for baby red colobus, which make up 75 percent of all kills. The situation is quite different in the Taï forest, where half of the chimp kills are adult colobus males (*see* "Dim Forest, Bright Chimps," *Natural History,* September 1991). Christophe and Hedwige Boesch have shown that the Taï chimps hunt cooperatively, perhaps because red colobus monkeys are harder to catch in the much taller canopy of the Taï rain forest. Successful Taï chimp hunters also regularly share the spoils. In contrast, each chimp in Gombe appears to have his own hunting strategy.

The single best predictor of when Gombe chimps will hunt is the presence of one or more estrous females in the party. This finding, together with the earlier observation by Geza Teleki (formerly of George Washington University) that male hunters tend to give meat preferentially to swollen females traveling with the group, indicates that Gombe chimps sometimes hunt in order to obtain meat to offer a sexually receptive female. Since hunts also occur when no estrous females are present, this trade of sex for meat cannot be the exclusive explanation, but the implications are nonetheless intriguing. Gombe chimps use meat not only for nutrition; they also share it with their allies and withhold it from their rivals. Meat is thus a social, political, and even reproductive tool. These "selfish" goals may help explain why the Gombe chimps do not cooperate during a hunt as often as do Taï chimps.

Whatever the chimps want the monkey meat for, their predation has a severe effect on the red colobus population. Part of my work involves taking repeated censuses of the red colobus groups living in the different valleys that form the hunting range of our chimpanzees. In the core area of the range, where hunting is most intense, predation by chimps is certainly the limiting factor on colobus population growth: red colobus group size in this area is half that at the periphery of the chimps' hunting range. The number of infant and juvenile red colobus monkeys is particularly low in the core area; most of the babies there are destined to become chimpanzee food.

Chimps in the Mahale Mountains of Tanzania also hunt red colobus monkeys. The chimps usually kill adult colobus, such as the one here, by bashing the animal against a tree limb or the ground.
Ferrero/Labat; AUSCAPE International

The proportion of the red colobus population eaten by chimps appears to fluctuate greatly from year to year, and probably from decade to decade, as the number of male hunters in the chimpanzee community changes. In the early 1980s, for instance, there were five adult and adolescent males in the Kasakela chimp community, while today there are eleven; the number of colobus kills per year has risen as the number of hunters in the community has grown.

Furthermore, a single avid hunter may have a dramatic effect. I estimate that Frodo has single-handedly killed up to 10 percent of the entire red colobus population within his hunting range. I now want to learn if chimps living in forests elsewhere in Africa are also taking a heavy toll of red colobus monkeys. If they are, then they will add support to the theory that predation is an important limiting factor on wild primate populations and may also influence some aspects of behavior. Meanwhile, I will continue to watch in awe as Frodo and his fellow hunters attack my colobus monkeys and to marvel at the courageousness of the colobus males that risk their lives to protect the other members of their group. ☐

Geneticists Out on a Limb

by David S. Woodruff and Phillip A. Morin

Few primate populations are better known than the chimpanzees of Gombe National Park. For more than thirty years, starting with Jane Goodall's innovative work, researchers have spent countless hours making notes on the most intimate details of the animals' daily lives. Extraordinarily valuable information has come from all this watching, but fieldworkers have been frustrated by not always knowing who was related to whom. To be sure, all Gombe chimps are identified and named by the researchers, and we can assume mothers carry their own babies. Establishing fatherhood, however, presents a problem, since a female may mate with up to twelve males during her period of sexual receptivity.

Until recently, Gombe workers had no way to fill in the gaps in their chimp family trees, for determining paternity would have required shooting darts into the animals and drawing blood samples. Not surprisingly, the researchers categorically ruled out such a procedure, which would have quickly undone all the years spent gaining the chimps' trust.

To overcome this problem, we developed a noninvasive method of genotyping based on DNA extracted from shed hair. (DNA can also be obtained from horns, antlers, feathers, and even feces.) To make use of this technique, however, we had to go out on a limb, literally. Adult chimpanzees sleep alone in a fresh nest of leaves they prepare in the trees each night. With help from our colleagues, including primatologists Janette Wallis, of the University of Oklahoma, and Jim Moore, of the University of California, San Diego, and the Gombe Stream Research Center staff, we watched the chimps make their nests, took note of who was in which nest, and then returned the next morning to climb the trees and search for hairs left behind in the abandoned beds. After one month, we had hair from all individuals in the Gombe community.

Practicing forensic primatology sixty feet up on branches too weak to support a leopard is not for the fainthearted, but the results were rewarding indeed. By studying variation in eight nuclear genes, we found that Gombe males are significantly more closely related to one another than are females. On average, these males are related at the level of half brothers. The sort of limited cooperation Craig Stanford observed among male chimps hunting colobus monkeys at Gombe may have evolved by kin selection: helping a relative with whom one shares genes can be the next best thing, evolutionarily, to helping oneself. Ongoing genetic studies of relationships in this community will eventually enable scientists to go back over the thirty years of observations and test all sorts of ideas about the evolution of behavioral patterns.

Similar genetic studies of chimpanzee communities elsewhere in Africa may also help us understand the significant behavioral differences between populations. Pascal Gagneux (a Ph.D. student working with the University of Basel's Christophe Boesch on the chimps of Ivory Coast's Taï Forest) is currently analyzing Taï chimp hair in Woodruff's lab. If male Taï chimps turn out to be even more closely related to one another than Gombe males, Gagneux's work might explain why Taï males cooperate more when hunting than their Tanzanian cousins do.

Obtaining hair samples from some twenty sites across Africa, we also investigated genetic variation among chimp populations. For this, we focused on two mitochondrial gene sequences. To our surprise, we found that the chimpanzees of West Africa are genetically quite different from those in Central and East Africa (including Gombe). This DNA work suggests that the West African chimps have been separated from the others for 1.5 million years—long enough to be regarded as a separate species by some authorities. If our result is supported by others, then *Natural History* correspondent Jared Diamond may want to change the title of his fascinating book about our own species from *The Third Chimpanzee* to *The Fourth.*

David S. Woodruff is a professor of conservation biology at the University of California, San Diego, where Phillip A. Morin completed his Ph.D. Morin is now at Sequana Therapeutics, Inc., in La Jolla, California.

Sentinels of Stone

Rooted in ancient tradition, Inuit signposts find a new life in art

Text and photographs by Fred Bruemmer

I spent summer and fall of 1967 on Coats Island in northern Hudson Bay with some scientists studying polar bears. Our camp was near the remains of a settlement of the now extinct Sadlermiut, arctic inhabitants who had died out early this century from a disease introduced by whalers. One day, contemporary Inuit walrus hunters passing our camp in their Peterhead boat gave me a lift to the north tip of Coats Island and left me there to observe the great murre colonies.

I was fifteen miles away from camp and anticipated an arduous walk along a coast cut by many steep-sided valleys. While still puzzling what route to take, I noticed a cairn, or pile of stones, on a nearby ridge. I walked over and saw another cairn inland, due south and half a mile away. From it, I saw the next cairn and a long line of them, strategically placed, leading me to camp by the easiest and most direct route possible. By luck, I had come upon an ancient trail that had linked the Sadlermiut's homes with the murre colonies, which were to them well-stocked larders of birds and eggs.

In Inuktitut, the language of the Inuit, the cairns I had stumbled upon are known

An inukshuk, or humanlike stone figure, stands on southern Baffin Island. With two legs but no arms, it may inform the savvy arctic traveler that a single route leads out of the nearby valley.

as *inukshuit* (singular *inukshuk*), which means "something acting in the capacity of a man." (*Inuk* is the singular for *Inuit*). In an empty land, an inukshuk seen in silhouette can look startlingly like a human. Some consist of only a few stones and are three or four feet tall, while others exceed twelve feet in height. Traveling northward in 1834 toward the Arctic Ocean on the river that now bears his name, Captain George Back, of Britain's Royal Navy, was amazed to see "a man" looking down from a high hill. Closer inspection revealed it to be a stone man "placed there by the Esquimaux."

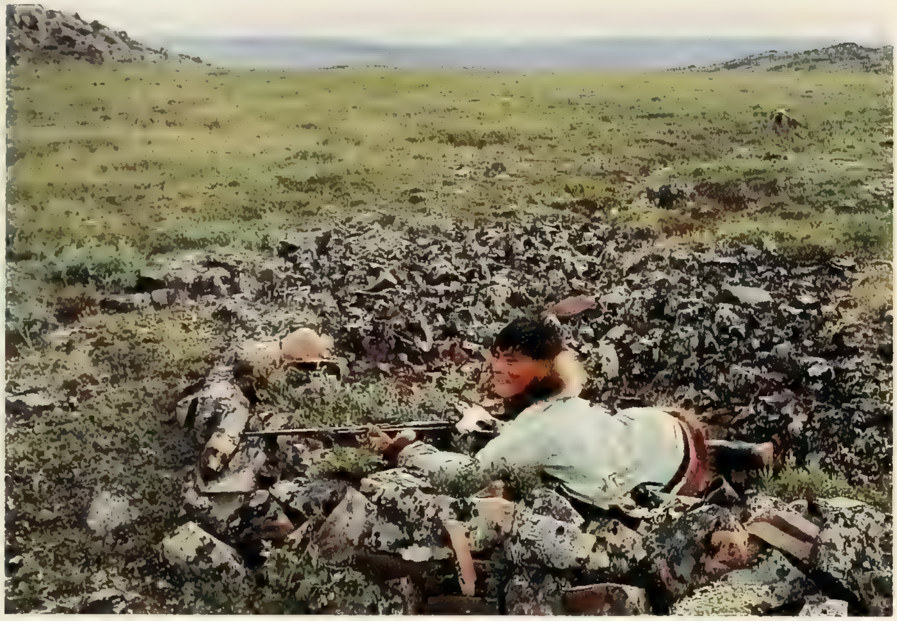
"Cairns of this type, which from a distance look like a man, are often found deep in the interior," wrote Heinrich Klutschak, a member of the American 1878–80 expedition across the Canadian Barrens. "They serve [as] signposts for the natives." Such inukshuit, however, often had hidden meanings that eluded white explorers.

Simeonie Aulaqiaq, an Inuk from Pangnirtung on the east coast of Baffin Island, recently explained that "in the Baffin region, the traditional meaning of an inukshuk has to do with direction. . . . An inukshuk on land with two arms and two legs means there is a valley, and at the end of the valley, you are able to go in two directions." An inukshuk with no arms but both legs points toward a single-pass valley, while an inukshuk without arms and legs "is simply a guide for a . . . hunter . . . when you stand beside one of them, you should be able to see the same kind of inukshuk somewhere in the distance."

Similar stone pillars guided Inuit seafarers traveling by umiak or kayak along the complex coasts of their realm. In the 1940s, while working in northernmost Labrador, the Canadian archeologist Douglas Leechman saw inukshuit "on many headlands . . . gazing steadfastly out to sea. Their principal purpose is to serve as landmarks, and an Eskimo knows the shape and color of every one in his district. Should he be overtaken by fog or bad weather he will often be able to save himself from going astray by the timely sight of a familiar cairn."

The north shore of Hudson Strait seems designed for the destruction of boats. Sheer-cliffed headlands jut out into the sea, and a maze of islands and skerries bars the way. Storms are frequent, tidal currents fierce, and "The Weather for the most Part, a stinking Fog," as the exasper-

Strategically placed, a row of crudely fashioned stone men, left, could frighten caribou and keep them running in a line toward hidden hunters. Below: George Hakungak, of Bathurst Inlet, wields his rifle in a shooting pit that was built by earlier bow-and-arrow hunters. His father, Ekalun, met some of the explorers who visited the Arctic early this century.



ated British explorer Captain Thomas James put it succinctly in 1631.

In his long lifetime of travel, the Inuk Ooloopie Killiktee, at whose camp I spent the summer of 1979, had mastered the intricacies of this complex and dangerous coast. Inukshuit helped. There were hundreds of them on strategic capes and mountains, and he seemed to know the position and meaning of each one. Some, he said, were made by the Tunit (the Inuit name for a prehistoric people known to archeologists as the Dorset Culture) and may have been built more than a thousand years ago. Others were relatively new; Killiktee remembered who had built them and why. And some he had constructed himself: to identify the entrance to an inlet where soapstone for seal oil lamps could be quarried, to indicate a safe passage between two islets, or simply to mark a place where he had camped.

Crossing Hudson Strait in skin boats was risky and the Inuit thought it wise to appease the spirits of sea and wind. "A long time ago near Cape Dorset [on southern Baffin Island] there was a special inukshuk," the Inuk Peter Pitseolak told historian Dorothy Eber. "In the old days people from our side who were going to cross [Hudson Strait] used to go to the inukshuk and give presents. They would say 'I give you this. I wish to return again.' "

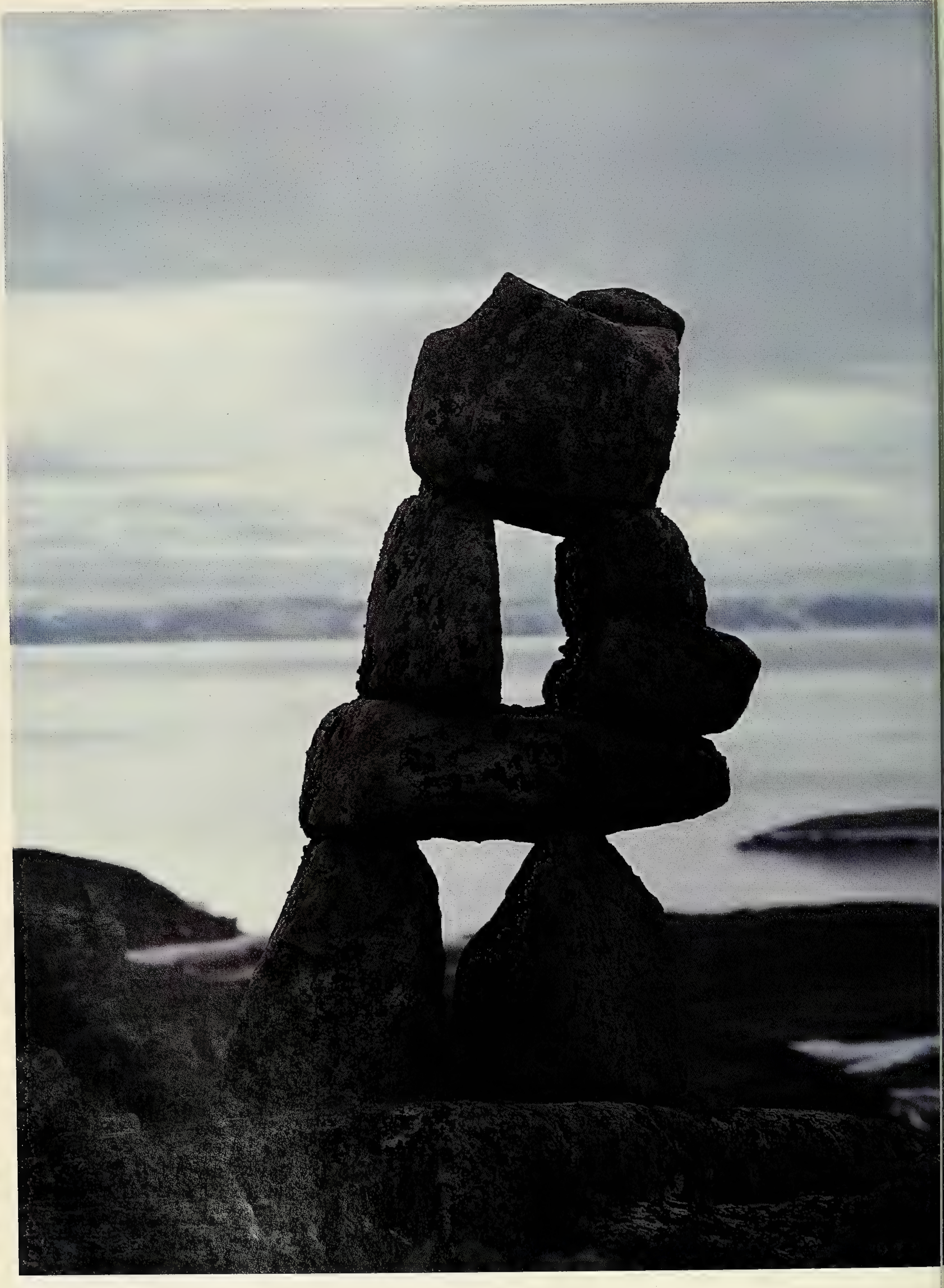
In 1965, Kiakshuk, the oldest man in Cape Dorset (he died in May 1966), told Brian W. Lewis, then principal of the Cape Dorset school, that "when men were about to make a long sea voyage they always made an inukshuk for good luck; invariably they left an offering to the sea spirits to insure their safety on the water."

Among their most important uses, inukshuit were aligned to funnel migrating caribou toward hidden hunters. Some of these alignments are extremely ancient. Curiously, these inukshuit are often just small mounds of stones, and it would take a very vivid imagination to see in them any resemblance to humans. Yet they worked, their efficacy based on the clever use of topography and expert, nearly intuitive knowledge of caribou behavior.

"The driving is started by the men giving long howls in imitation of wolves," wrote the explorer Vilhjalmur Stefansson. "This generally makes the caribou restless and starts them moving slowly" toward the long line of inukshuit "set up from fifty to a hundred and fifty yards apart, according to the character of the topography."

Frightened by the howling and the sudden appearance of humans, Stefansson noted, the caribou's "imagination appears to turn all the little monuments into a line of people. It seems absurd that two stones, one on top of the other, reaching an elevation of only a foot, should be feared as much by the caribou as actual persons, but that appears to be the fact. It seldom happens that the animals break through the line and usually they are driven at a speed from five to eight miles per hour toward the ambush."

Among the precontact Inuit "discovered" by the 1913–18 Stefansson-Anderson expedition was a ten-year-old boy named Ekalun. Fifty-four years later, I lived at Ekalun's camp in the Bathurst Inlet region of arctic Canada, sharing his tent for six months and, when he was in a reminiscent mood, his immense knowledge of Inuit life and hunting techniques.



A distinctively shaped inukshuk high above Hudson Strait, left, served as a landmark for Inuit navigators traveling by umiak or kayak. A squat inukshuk, below, stands near an old campsite on Somerset Island.

Caribou were essential to Inuit. They provided food and, most important, the best fur for arctic clothing. Seven skins were required to dress a man, a woman required six, and a child four. The Inuit made every effort to kill caribou for winter clothing in August and early September, when the fur was of optimum quality.

This was also when the caribou that had spent the summer on far-north tundra pastures began their southward migration, which brought some herds to elaborate inukshuk systems that channeled the flow of animals toward waiting hunters armed with bows and arrows or with lances. One such inukshuk system, similar in concept and design to several others I have seen in the Arctic, was twenty miles inland from Ekalun's coastal camp, and he had hunted there for many years, as a boy driving the caribou and, later, as a man and hunter waiting for them in shooting pits.

The traditional ambush required three main elements. The first was an extensive area of lush arctic meadow where migrating caribou naturally bunched and browsed. From there two long rows of inukshuit were arranged to lead the caribou for many miles, converging at some natural defile—a narrow pass where the caribou would be forced to proceed uphill in a thin line. And finally, shallow shooting pits with low rims of rocks were prepared for the hunters, usually at the top of the defile.

The hunt began, said Ekalun, with boys and young men circling the herd and driving it slowly, cautiously toward the entrance between the two inukshuit alignments. Once in the pillar-flanked passageway, the caribou were kept trotting forward and uphill. Whenever they veered toward one side, women and children, hidden behind some of the inukshuit, jumped out, waved their arms, flapped long strips of white caribou belly fur, and screamed. " 'Hoo-hoo-hoo,' they howled, just like wolves," Ekalun recalled. To make the inukshuit more realistic, people placed lumps of sedge-covered sod on the tops of many of them to give them a mop-headed appearance.

Terrified by the people, the howling, and the lines of stone men, the caribou rushed forward toward apparent safety: the open defile with its hidden hunters. The men waited, tense with excitement, until the caribou were within a few feet, then shot them with their bows or speared them with lances.

The weakness of the Inuit bow made the inukshuit-directed caribou drive essential. Made of pieces of driftwood, brittle and fragile, the Inuit bow was ingeniously carved and pegged together, backed with plaited sinew cord to give it spring, and lashed with caribou or seal leather to give it strength. But it remained an ineffectual weapon compared with bows of other regions where suitable wood was available. The longbow made of yew used by English archers to win the battle of Crécy in 1346 was deadly at 200 yards and more. The Inuk bow, said Ekalun (who was married before he had his first rifle), killed from no farther than thirty paces.

Since the stone men and their purpose remained immutable, such ambush systems were used for centuries and belonged, in Inuit fashion, to all the people. Anyone could use it. When I asked Ekalun (who found the white man's mercenary ways deplorable) who could use the system, he said sarcastically: "Anyone who paid $500!" In the 1960s, the Canadian archeologist William E. Taylor, Jr., examined an "elaborate inukshuk system . . . extending over an area of about two square miles" on southern Victoria Island in the Canadian Arctic. Much of it had been built more than a thousand years ago by Dorset Culture hunters. It was subsequently used by Thule Culture people and "by recent Copper Eskimo people."

Both Taylor and the American archeologist Moreau S. Maxwell, who studied "inukshuit drives" on southern Baffin Island, speculate that this type of hunt, apart from procuring food and furs in their prime, also had social importance. Inuit camps in Canada, from the remotest past until the 1950s, consisted usually of about twenty-five to thirty individuals, presumably an optimum number for mutual support. Men normally hunted alone or occasionally in pairs. But the caribou drive, Taylor observed, required the "co-operative action of a sizeable number of people meeting at least annually." It was a time, said Maxwell, when "a number of bands may form a virtually structureless aggregate of 100 or more people."

That was roughly how Ekalun remembered it: a joyous get-together of many bands from an area about half the size of Belgium, the exchange of stories and gossip of an entire year, the thrill of the hunt followed by marvelous feasts. Once Inuit acquired guns, however, caribou drives were abandoned. Most Inuit moved into villages and towns, and the meanings and messages of inukshuit that once served as guides and beacons were gradually forgotten. The stone men stood alone in an empty land.

Since Canadian law forbids the disturbance of archeological sites and the removal of ancient artifacts from the North, inukshuit have rarely been damaged or destroyed. Their very size and weight discourages pilfering and smuggling. But in recent years, outsiders have coveted these stone men as objects of art. Such a concept is alien to the Inuit. Puzzled but pragmatic, they have nevertheless begun to build inukshuit for money.

The first big commission came from the Toronto airport (now the Lester B. Pearson International Airport). Since, as a plaque states, "these stone figures are among the oldest transportation symbols" of humankind, they seemed an appropriate link between the Stone Age and the jet age. Three inukshuit, made of Baffin Island granite, were assembled on Cape Dorset in the early 1960s under the direction of Kiakshuk. They were marked stone by stone, photographed, and then shipped to Toronto for reassembly. The main figure, with an upraised arm and a powerful cubistic face that Picasso or Braque would have loved, was described by the British art expert Charles Gimpel in 1967 as "the best Canadian sculpture I have seen."

An inukshuk commissioned as a sculpture for the international airport in Toronto, below, links the Stone Age to the jet age. Opposite: Placed near the northeast coast of Hudson Bay, a huge inukshuk may have guided past travelers to the mouth of the Pangnirtung River.

Many public and private commissions followed and inukshuit now stand on elegant urban properties and near many public buildings. One stone man stands in a strangely sylvan setting at the Ontario Science Centre in Toronto. Another, made by Kellypallik Pishuktie of Iqaluit on Baffin Island, was placed at the entrance to an exhibition entitled "Contemporary Inuit Masterworks," first displayed at the United Nations in New York and then at the Earth Summit in Rio de Janeiro during the summer of 1992.

Once guides to Inuit travelers, the rugged stone men of the Arctic are now the *dernier cri* in elegant *salons d'art.* Ekalun, my old friend and mentor, who only knew inukshuit in the wild, would have been amused, but I think also pleased by this transformation. □

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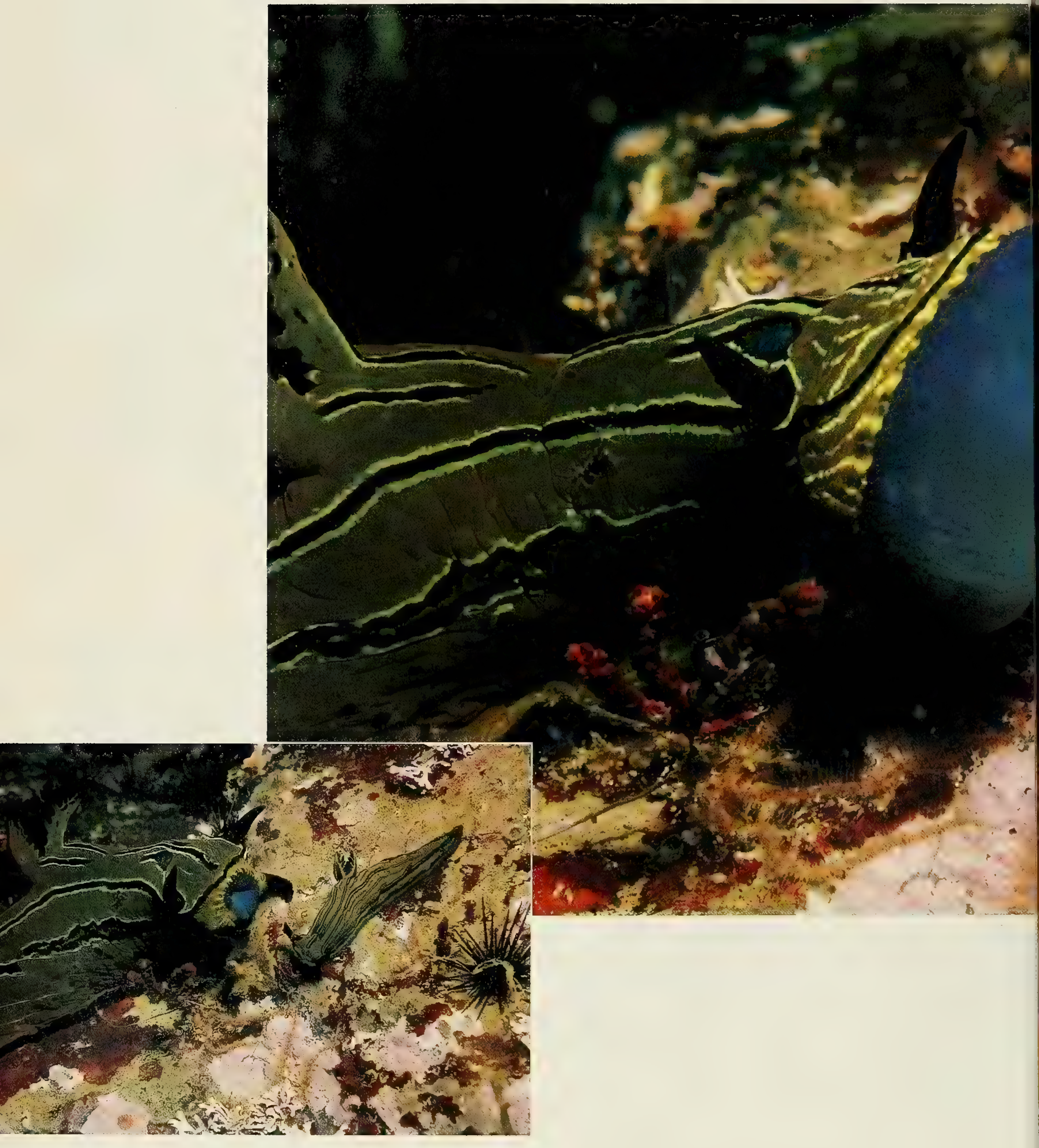
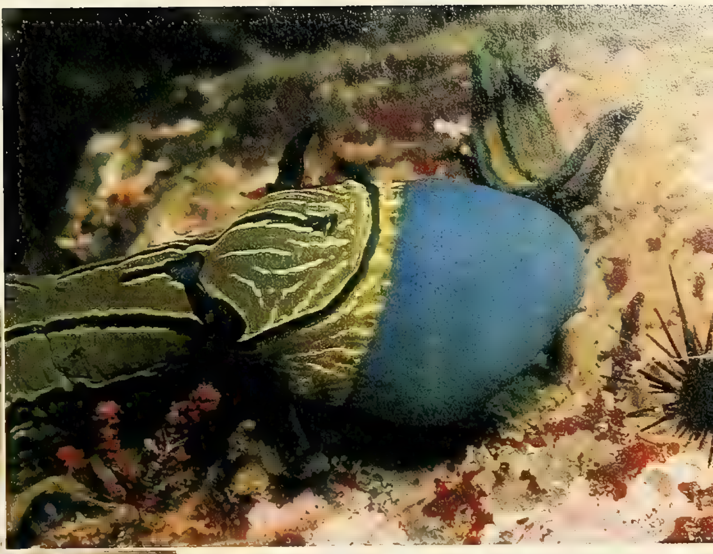
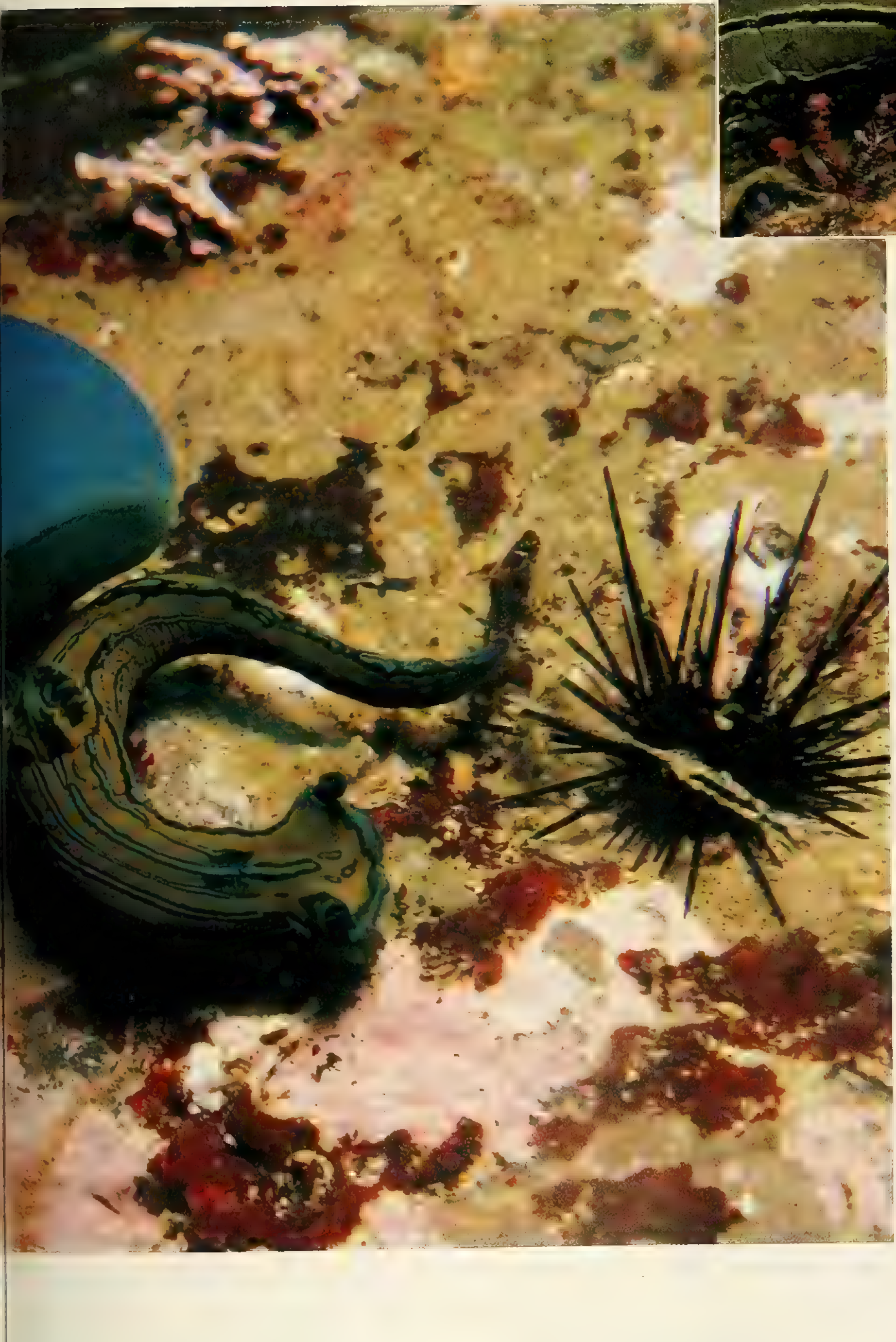
Attack of the Sea Tiger

Sea slugs are not always sluggish

Photographs by Chris Huss







It has no backbone and doesn't look much like a tiger, but this colorful nudibranch, or sea slug, does flaunt black stripes on a tawny field. A carnivore that silently stalks and feeds on other slugs, the "sea tiger" will even attack members of its own species. Both blind and deaf, it must follow a chemical trail exuded by its prey. Then, using its large, hooklike toothed radula to pull victims into its mouth, the foot-long predator swallows them whole.

This encounter between a small sea tiger (about four inches long) and a smaller blue-striped slug occurred about fifty feet underwater off Isla San Pedro Mártir, in Mexico's Gulf of California. Both sea tigers and blue-striped slugs are restricted to warm Mexican waters. At first, the sea tiger slowly approached its intended prey, far left, until it was within striking distance. When in position, the hunter lunged at the smaller invertebrate, left. But the moment it felt the sea tiger's sawtoothed radula, the blue-striped slug was stung into action. Rapidly bending and unbending several times, above, the intended meal propelled itself out of harm's way.—*R.M.*

Stressed to Kill

by Steven Austad

At an earlier time of my life, before becoming domesticated and deskbound in academia, I spent a fair amount of time carousing with a gang of Hollywood stuntmen. During the day, these maniacs routinely dived in front of speeding trains, leaped off exploding bridges, or rolled burning cars down mountainsides. At night, those who hadn't landed in the hospital gathered at the pub where they laughed, lied, and played marginally sublethal practical jokes on one another, never apparently giving a thought to how close they had come to dying that day or to the hazards of tomorrow. According to Robert Sapolsky, these bouts of boozy and forgetful relaxation were exactly the right way to manage the stress in their lives.

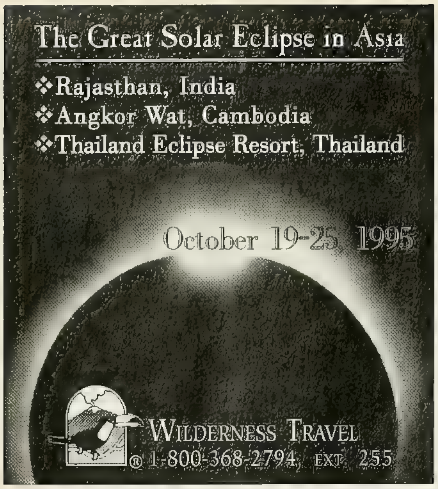
Sapolsky ought to know. He has spent his professional career studying the physiology of stress, specifically how steroid hormones called glucocorticoids, which are released in quantity during stress, affect the brains of rats. But their effect on brains isn't the half of it. In his new book, *Why Zebras Don't Get Ulcers,* Sapolsky gives us chapter and verse on how chronic stress can disrupt our digestion, damage our stomach lining, stiffen our arteries, stunt our growth, devastate our sex life, cripple our immune system, and, conceivably, hasten our aging rate. You might think that reading three hundred and some pages on this subject would be about as appealing as a dentist with a dull drill, but you would be wrong. The book is a page-turner and is anything but depressing or disheartening.

Stress, defined by physiologists, isn't only the sort of mental anxiety that we commonly associate with a visit by a tax auditor. It is also any exceptional physical demand on the body, such as fleeing from a mugger or saving a child from drowning. For this sort of physical stress, our bodies are superbly designed to respond in an adaptive manner—stress hormones sharpen our senses, dull pain, and redirect energy from immediately nonessential activities, such as digestion or tissue repair, to the appropriate muscles for flight or combat. Sapolsky's point in the title of the book is that while the life of a zebra is dominated by brief physical stresses, the life of a modern human is dominated by chronic mental stress. The same hormones that are so adaptive in short bursts become destructive in longer bouts.

This idea isn't new. Hans Selye, grandfather of stress physiology, developed it nearly fifty years ago. What is new, and what is explained by Sapolsky with witty lucidity, is an appreciation of chronic stress's many destructive mechanisms. For instance, he explains the damaging effects of overexercise by noting how he might try to convince hunter-gatherers from the African savanna that in our culture some presumably sane people actually run twenty-six miles just for exercise. He also gives us an understanding of how stress's effects may accumulate later in life and, perhaps most importantly, what psychological and physical factors might minimize the effects of stress. For instance, Sapolsky and colleagues discovered that if newborn rats are gently handled for fifteen minutes per day during the first few weeks of their lives, their glucocorticoid levels are lowered for the remainder of their lives.

WHY ZEBRAS DON'T GET ULCERS, by Robert M. Sapolsky. *W. H. Freeman & Co., $21.95; 368 pp., illus.* STRESS, THE AGING BRAIN, AND THE MECHANISMS OF NEURON DEATH, by Robert M. Sapolsky. *The MIT Press, $55; 429 pp., illus.*

One thing that sets Sapolsky apart from most of his colleagues in the field of neu-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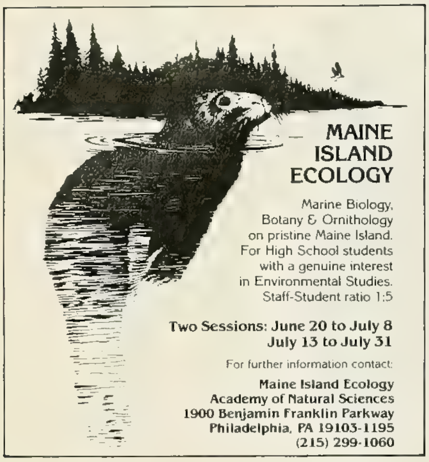
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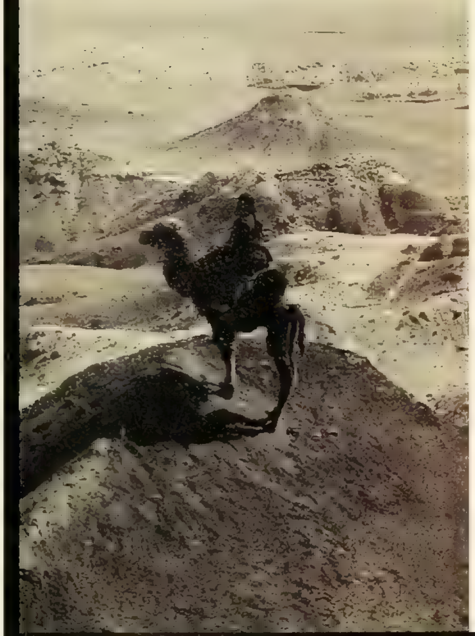
roendocrinology is that he is not locked to his lab bench. Every year he ventures to East Africa to study stress in wild baboons. This is where he hopes to learn something about coping with stress that might be directly applicable to humans. With the prejudice of a field biologist, I think this annual experience gives him a perspective not frequently found in the biomedical community: an appreciation of the adaptive value of physiological traits. He knows that something can be learned by observing how animals cope in nature.

In his study population, male baboons have plenty of food and few predators. Their main source of stress seems to be their involvement in a male dominance hierarchy that seems to be equal parts psychological and physical combat, what you might expect in a tough prison. Stress level, of course, is related to dominance rank, but astonishingly, good and bad copers are found among all the ranks. Correlating the behavior he observes with the glucocorticoids he measures in the baboons' blood, Sapolsky finds that the best-coping males are socially perceptive (quickly able to distinguish threatening from nonthreatening social situations), proactive (quick to attack rather than procrastinate when the situation warrants), and adaptable to changed social conditions. The response of the least-stressed males to a physical fight is to accept the consequences of defeat or victory, and once the fight is over to forget about it. This was precisely what my stuntmen friends were so good at—not fretting about the past or worrying about the future. They were satisfied simply to have survived another day.

Part of the reason this book is an exceptionally enjoyable read is that Sapolsky is so obviously thrilled with his subject. "I am in love with these hormones," he says. Also, because stress influences virtually



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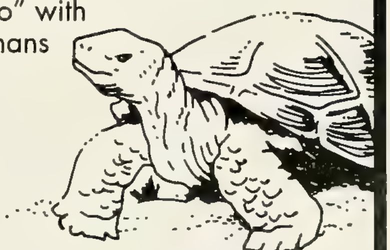

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every organ we have, he has a chance to take us on a bodily tour, explaining some wonderful physiological tidbits, such as how a voodoo death curse probably works, how to tell whether impotence is physiological or psychological, or why extreme fright can lead to loss of bowel or bladder control. His explanation of why chronic throbbing pain can be relieved by a brief sharp pain made me, at least temporarily, reconsider the desirability of rubbing stinging nettles on an already painful area, as the villagers I work with in Papua New Guinea do. Perhaps I'll even give it a try next trip.

Sapolsky also has a wonderfully oblique and unpredictable way of explaining physiology. In a book on stress, who would have expected quotations from *Lady Chatterley's Lover* and the poetry of W. H. Auden, or a discussion of the physical stature of J. M. Barrie (creator of Peter Pan)? He even includes an anecdote on how the practice of grave-robbing led (by a complicated route) to the now-discredited medical practice of irradiating babies' throats as prevention against sudden infant death syndrome.

Sapolsky's major personal contribution to the scientific literature on stress concerns how exposure to glucocorticoids can indirectly damage a part of the rat brain called the hippocampus, which is involved in learning and memory, and how this damage becomes self-accelerating with normal aging. If the human brain is similarly damaged, it is major news, not only because hippocampal damage is extensive in the major neurological disease of aging—Alzheimer's—but also because a sizable number of Americans now take synthetic glucocorticoids regularly. After having a double knee replacement, Joe Namath, for instance, recently revealed that he had been taking glucocorticoids regularly since the early 1960s. In addition to professional athletes, asthma and arthritis sufferers also take these hormones, and last year a panel convened by the National Institutes of Health endorsed giving glucocorticoids to all expectant mothers in danger of giving birth prematurely.

The details of his research on glucocorticoids and hippocampal damage, and more theoretical ideas about how the hormones might be involved in normal aging, can be found in Sapolsky's technical book, *Stress, the Aging Brain, and the Mechanisms of Neuron Death.* Sapolsky's pet hypothesis, explained at length, is that chronic stress increases the hippocampus's vulnerability to injury from other sources, and that the brain's cumulative exposure to glucocorticoids over a lifetime can lead to a number of normal changes we associate with aging.

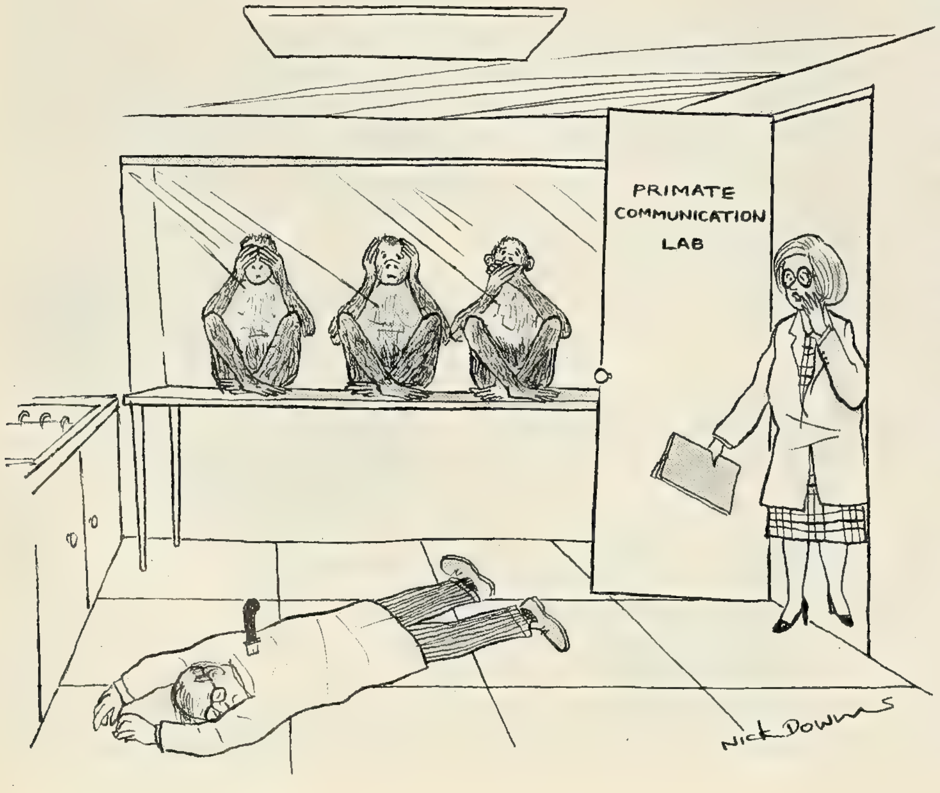
These ideas are controversial. Despite the rat research and a few anecdotal accounts of accelerated cognitive decline in victims of concentration camps and in children with head injuries, we have precious little evidence that excessive glucocorticoids damage the human hippocampus. Many thousands (maybe even millions) of humans have taken synthetic glucocorticoids for decades, and unusual memory loss or learning impairment has not been documented. And yet, among laboratory rodents, the only proved method of retarding aging—restricting dietary calories by 30 to 40 percent—is associated with *higher* glucocorticoid levels. And in most behavioral measures, including tests of memory, the calorically restricted rodents perform better later in life than fully fed animals.

These factors do not disprove Sapolsky's hypothesis, of course. There may be subtle learning and memory problems with people on long-term medication that have gone unnoticed. Also, the calorically restricted rodents may have some way of protecting their brains against the effects of glucocorticoids and therefore have good memories in their dotage despite their glucocorticoid levels. But certainly, if large numbers of pregnant women are about to be prescribed synthetic glucocorticoids, it is imperative to clarify how these hormones affect the fetal brain.

This book will require real effort and supplemental reading by readers not already fairly fluent in neurobiology. However, people who develop a driving interest in stress and the brain will find in this book all the information needed to understand the continuing debate. The book is much more lucidly written than most books on technical medical issues, as you might expect, but the topic is both subtle and complex. The mechanistic details of the stress response (so far as they are known) remind me of a quip about quantum physics: "If you are not confused, then you haven't properly understood it."

You certainly won't be confused by Sapolsky's popular writing. Unlike most scientists, who can beat the most gripping topic into lifelessness, he enlivens whatever he touches. The real test of how much we enjoy a book can be answered by the question, "Would you read it on a plane at the beginning of a vacation?" Indeed, *Why Zebras Don't Get Ulcers* would be a perfect airplane book.

Former lion trainer Steven Austad is now an associate professor in the Department of Biological Sciences at the University of Idaho. He studies evolutionary biology and the biology of aging and combines laboratory research on opossums with fieldwork on the arboreal marsupials of Papua New Guinea.



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Romancing the Mountaintop

by Neil de Grasse Tyson

> I know that I am mortal by nature,
> and ephemeral; but when I trace, at my
> pleasure, the windings to and fro of the
> heavenly bodies I no longer touch
> earth with my feet: I stand in
> the presence of Zeus, himself, and take
> my fill of ambrosia.
>
> *Claudius Ptolemy*

I have never met Zeus nor have I ever tasted ambrosia, but I am no less seduced by the offerings of the universe than was Ptolemy in the second century A.D. Once or twice each year, I travel to any of several mountaintop observatories in the world to obtain data on curious objects in the universe. One such trip takes me from Princeton, New Jersey, to the Cerro Tololo Inter-American Observatory in the Andes Mountains of Chile.

The nighttime sky of the Southern Hemisphere offers a different assortment and orientation of cosmic objects from that of the Northern Hemisphere. This is particularly important to me because at 30° south latitude—the location of Cerro Tololo—the center of our galaxy rises at sunset, sets at sunrise, and passes directly overhead at midnight in June. A large part of my research involves the attempt to understand the structure of our Milky Way within about three degrees of the galactic center. Otherwise known as the "galactic bulge," it is a slightly flattened, bulbous region that is packed with more than ten billion stars—about 10 percent of the galaxy's total. When observing the nearest galaxies, one can typically identify only the brightest of their giant stars. The remaining billions blur into puddles of light. For this reason, the ability to observe individual stars in our own galaxy provides our best insight into the structure of all spiral galaxies.

Some telescope sites are nearby and easy to get to, but others require extensive travel arrangements. To come in cosmic contact with the galactic bulge, I must first submit, half a year in advance, a six-page proposal that outlines the planned observation, defends its worthiness as a scientific project, and describes in detail the requisite hardware. Observing time is awarded competitively, and, typically, no more than a quarter of the applicants for the mountain's largest telescopes are given time. Allocation committees parcel out time in blocks that are typically four to six nights, but may be as short as two. No allowance is made for bad weather, which can simply mean overcast—rain and snow storms are no worse.

A week or two before the observing run, I prepare detailed coordinates, assemble finding charts, and collect assorted manuals and notes from previous observing runs that will be useful at the telescope. Then comes the trip. The flight from Princeton to Santiago is 5,000 miles due south. In June local time does not change, which is not at all helpful when you are trying to adjust to being awake at night and asleep during the day. You will never find an astrophysicist who complains about ordinary jet lag because the largest possible jet lag is twelve hours, and this is precisely what you get when you invert your schedule to become nocturnal. In this transformation, a time zone change only helps.

My pilgrimage begins with a forty-five-minute drive from Princeton to Long Term Parking Lot D at Newark International Airport. And then comes a fifteen-minute bus ride to the airline terminal, a two and one-half hour flight to Miami International, a two-hour layover, a seven and one-half hour flight to Santiago International, a forty-minute (hazardous) taxi ride to the observatory guest house in downtown Santiago, an eight-hour layover, a twenty-minute (less hazardous) taxi ride to the Santiago bus station, a seven-hour bus ride north—up the coast along the Andes—to the observatory's headquarters at La Serena, a night there, and finally a one and one-half hour van ride up the Elqui Valley to the summit of Cerro Tololo. The warm clothes I have brought insulate me from the cold of the Chilean mountain winter, which intensifies as I near the summit. I also keep a keen eye on the sky for the giant South American condors, whose effortless ascent on the mountain thermals portends a night of difficult observing. Once on the mountaintop, I have twenty-four hours to complete the nocturnal inversion before my date with photons from the galactic bulge begins.

Or one can look at it another way. The well-traveled photons began their journey near the center of our galaxy about 26,000 years ago, rendering them contemporaries of Cro-Magnon. My journey (much shorter perhaps, but with no less drama) took only three days. We meet at a detector positioned in the focal plane of the telescope. I can't help contemplating the fate of the photons not collected by the telescope's giant mirror. Imagine a journey of 26,000 light-years only to miss the telescope and slam into the mountainside. Most of the photons miss Earth completely and are still speeding through interstellar space. Those I collect, however—those snatched from the photon stream—are the basis for most of my research.

The moment has arrived: Time is cherished; clouds are despised; photons are coveted. The observatory is now my temple, complete with a dome, a telescope, and a dimly lit control room with two dozen computer monitors that continuously display updated information about the telescope, the detector, the object being observed, the ongoing preliminary data reductions, and the local weather.

Assisting me in the control room is a

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renowned colleague and friend of mine who is a pure theorist, which simply means he does not necessarily know one end of a telescope from the other. We are two out of three collaborators on a project to obtain original data on the heavy element abundances and the velocities for thousands of stars, which will enable us to decode some details of the history and structure of the galactic bulge. My theorist colleague had never been to a large optical telescope, so I thought it would be a good idea to haul him all the way to Cerro Tololo. But five hours after he enters the observatory building, central Chile experiences a 6.5 earthquake, the detector's optics are shaken out of alignment, and several hours of data are corrupted. Either the observer gods were upset because a pure theorist entered sacred ground or the Andes are geologically active. Regardless, next time I may leave him at home.

At home, our offices are equipped with powerful computer workstations where we conduct extensive data reduction and analysis. Not unlike evolutionary biologists who interpret time scales from fossil evidence in sedimentary rock, we infer a history of star formation for the galactic bulge from the heavy element enrichment among its stars. As prescribed by the big bang theory for the origin of the universe, the first gas clouds—and the first generation of stars formed from them—were composed of pure hydrogen and helium.

Most of the heavier elements came later, created by supernovae, those rare, titanic explosions of massive stars in their death throes. Loaded with heavy elements, ejecta from supernovae enriched the gas clouds from which the next generation of stars formed. For each subsequent generation of stars, the level of heavy elements continued to rise.

While some stars die shortly after they are born, most stars live for many billions of years, so that when we observe the galactic bulge we see a beehive mixture of multiple stellar generations. By comparing the number of stars with low heavy-element abundance with those of high heavy-element abundance, we can begin to untangle the history of star formation. And because the light from the stars also carries information about their velocity, we can derive useful information about the mass, the gravity, and the origin of the bulge's structure.

To draw scientific conclusions of high confidence requires data of high quality. An excellent night at the telescope requires the very best seeing conditions. From uneven heating and cooling of the earth's surface, however, the lower atmosphere can be a turbulent place of rising and falling air currents. What is good for condors is bad for astrophysicists. One consequence is that a star's image becomes an undulating blob of light on the detector, which seriously compromises observing efficiency and data quality. For your own safety, do not ever tell an astrophysicist, "I hope all your stars are twinkling."

As one climbs through the lower atmosphere, the pressure drops exponentially, so that the top of a mere 7,000-foot mountain (the elevation of the Cerro Tololo observatory) sits above nearly 25 percent of the earth's air molecules, with a corresponding 25 percent drop in atmospheric pressure. These observing conditions dramatically improve most astronomical data. A mountain twice this height, such as Mauna Kea in Hawaii, home of the world's largest optical telescope, is above 40 percent of the earth's atmosphere and is the location of some of the finest ground-based observations ever made. That mountains tend to be ideal venues for cosmic inquiry did not escape Sir Isaac Newton in his 1704 treatise on optics:

> If the Theory of making Telescopes could at length be fully brought into Practice, yet there would be certain Bounds beyond which Telescopes could not perform. For the Air through which we look upon the Stars, is in a perpetual Tremor; as may be seen by the . . . twinkling of the fix'd Stars.

Sir Isaac continued with telescopic foresight:

> The only Remedy is a most serene and quiet Air, such as may perhaps be found on the tops of the highest Mountains above the Grosser Clouds.

An even better "remedy" is found in the Hubble Space Telescope, which was lifted into orbit primarily to escape the degraded image quality and poor resolution that the lower atmosphere imposes on observations of all objects.

I end the final night of the observing session as I listen to one of those bombastic classical music finales on the observatory's CD player. (One of my favorites is the end of Beethoven's Ninth Symphony.) I close the observatory slit, which generates a sound that, as you might expect, resonates in the telescope dome with the acoustic richness of your bathroom shower, and I emerge from the dome.

Dark time, that most coveted sequence of observing nights when the moon is near its new phase, insures that at the end of an observing run of more than four or five days, twilight will contain the rising thin crescent moon low on the horizon, framed in the layered colors of the dawn sky. When viewed from a mountaintop, the presunrise horizon light is as bright as when viewed from sea level, but the surrounding sky, which has yet to be dissolved by dawn, is much deeper in its darkness. The result is a stirring sweep from the rich remains of the night sky overhead to the radiant twilight on the eastern horizon.

With my little piece of the universe transferred to a high-capacity data tape in my breast pocket, I now return home with two backup tapes secured—one in my checked luggage, and one left behind on the mountain.

But times change.

Princeton University's Department of Astrophysical Sciences is part of a consortium of five institutions (including the University of Chicago, the University of Washington, New Mexico State University, and Washington State University) that own and operate a 3.5-meter telescope at Apache Point, New Mexico. This is a 9,200-foot summit near the town of Sunspot, home of the National Solar Observatory. What makes the Apache Point telescope unusual is that it was conceived and constructed to be run over Internet lines from independent control rooms located at each member site. The Princeton control room is in a specially outfitted space that was carved into the department basement. In principle, the only difference between observing remotely at Apache Point and observing on location at Cerro Tololo is the length of the wires that connect to the back of each console.

For many types of observing projects, now all I need do is walk for about ninety seconds from my office door to the basement observing room. Yes, it looks, smells, and feels like a real observing room—complete with a CD player and subdued lighting. But as efficient as remote observing is, one cannot deny the absence of a mountain's majesty. For better or worse, I suppose there will come a time when I tell my grand-graduate students, "Back in the old days, the data didn't just appear on our doorsteps. We traveled great distances. We ascended great mountains. We met the universe and its photons face to face."

Neil de Grasse Tyson is an astrophysicist who holds a joint appointment at the American Museum–Hayden Planetarium and Princeton University.

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CELESTIAL EVENTS

by Joe Rao

A close conjunction of the moon and a bright star or planet is always an impressive sight, and this month we have three conjunctions gracing the predawn skies within a five-day period. The first occurs in the early morning of the 23d, when Spica, the brightest star in Virgo, disappears behind the bright limb of a waning gibbous moon. (Spica, which is 280 light-years away, emits as much light as 2,300 suns.) This conjunction may be hard to see without a small telescope because the glare from the moon's sunlit edge may obscure the star. Spica's reappearance, on the other hand, will be spectacular, as the star springs into view from behind the moon's dark edge. Its sudden emergence should be easy to see with the unaided eye, except perhaps along the East Coast, where morning twilight will already be well advanced.

Three mornings later, the moon—now a thinning crescent—will be positioned off to the upper right of Jupiter. The most eye-catching spectacle of all, however, will occur on the morning of the 27th, when the moon slips just off to the south of brilliant Venus. For South American viewers, the moon will occult Venus in much the same way it did Spica. Unfortunately, North Americans will be outside the occultation zone, but we will still have an excellent view of the moon passing below Venus at a distance less than its own diameter. The sight will be enhanced by "earthshine," the light reflecting off our planet, which will faintly illuminate the dark portion of the lunar disk. The moon and Venus will appear closest together at about 6:00 A.M., EST. After sunrise, see if you can keep both the moon and Venus in sight during the daytime.

THE PLANETS IN JANUARY

Mercury emerges from the solar glare and into the evening twilight early in the month. On the 19th, Mercury reaches its greatest elongation, east of the sun. Fading rapidly, the planet is not likely to be seen after another week.

Venus glimmers more brightly in January than at any other time in 1995. It starts the new year at magnitude -4.4, nearly thirteen times brighter than Jupiter. All month it rises in the southeast at least an hour and a half before the first light of dawn. Don't miss the spectacular pairing of the crescent moon and Venus on the morning of the 27th.

Mars, in the constellation Leo, will nearly double its brightness in January as it draws closer to the earth. Moving westward among the background stars, Mars is in the midst of a conjunction with Leo's brightest star, Regulus. Watch Mars gain in brilliance relative to Regulus all month. As January begins, Mars will be rising out of the east–northeast at about 8:30 P.M. local time.

Jupiter, like Venus, is a brilliant morning star and is in the southeast as twilight begins. For the first eleven months of 1995, Jupiter will be found within five to seven degrees of the red-hued star Antares, which the planet will pass three times this year. The first pass occurs this month on the 23d; the others will follow on June 7, with Jupiter in retrograde motion, and on September 25, after the planet has resumed eastward motion. A lovely crescent moon will be found to the upper right of Jupiter on the morning of the 26th.

Saturn glows yellowish white at magnitude 1.2 amid the faint stars of Aquarius. It sets in the west–southwest just after 9:00 P.M. on the 1st, but before 7:30 P.M. by month's end. Soon after sundown on the 5th, Saturn can be found on a line well below and slightly to the left of a thin crescent MOON.

The **Moon** is new on the 1st at 5:57, A.M., EST; first quarter is on the 8th at 10:47 A.M.; full moon is on the 16th at 3:27 P.M., EST; and last quarter occurs on the 23d at 11:59 P.M., EST. A second new moon appears this month on the 30th at 5:48 P.M., EST.

Earth arrives at perihelion, its closest point to the sun at 6:00 A.M., EST, on the 4th, when the sun, will be only 91,400,000 miles away.

The **Quadrantid meteors** will be visible to early risers on the 4th. These bluish white meteors, which streak from an area of the northeast sky near the end of the Big Dipper's handle, are named after the now-defunct constellation Quadrans Muralis. This is a short-lived display, not likely to produce more than forty shooting stars an hour.

Joe Rao is a meteorologist and a guest lecturer at the American Museum–Hayden Planetarium.

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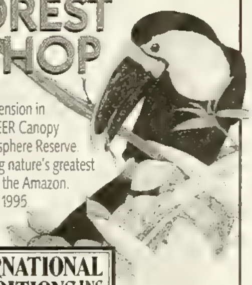

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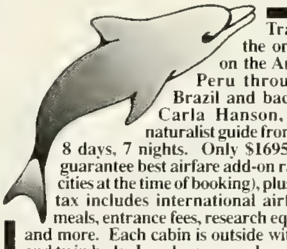

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Falling into a Rut

Oblivious to a mid-October snowstorm, two Dall's sheep rams lock horns in Alaska's Denali National Park. While this pre-rut tête-à-tête may have an element of competition, these rams, part of a group of three traveling in search of ewes, are merely reaffirming who's who in the hierarchy. Even during the height of the rut, Dall's rams—unlike bighorn sheep—only occasionally engage in head-battering violence.

The older ram stood uphill with his head lowered, and the subordinate, as decorum dictates, approached and initiated a ritual of forehead rubbing. After a few minutes he locked horns with his superior and then gently moved his own head about, as if attempting to break free. Although seemingly stuck together, the rams quickly disengaged and looked around whenever something caught their attention. The rubbing and horn-locking continued for five minutes.

Valerius Geist, a biologist who studies such behavior, speculates that the subordinate ram may be anointing himself with oils from the dominant ram's preorbital scent glands, located just forward of the eyes. The oils may then help identify the subordinate as a familiar ram, one whose status need not be contested. Dall's rams have only a relatively short time to mate. After they reach breeding status (usually in seven to ten years, when their horns form almost a full swirl), they generally live only another five years or so.—*R. A.*

Photograph by Craig Brandt

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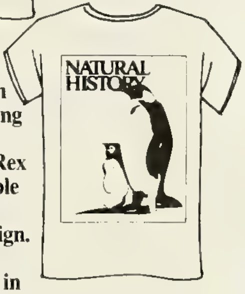
NATURAL HISTORY



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AT THE AMERICAN MUSEUM OF NATURAL HISTORY

EXPEDITION: TREASURES FROM 125 YEARS OF DISCOVERY

As part of its 125th-anniversary celebration, the American Museum of Natural History has developed a special exhibition that leads visitors on an "expedition" through the Museum. Fifty "treasures," selected from the Museum's collection of more than 30 million artifacts and specimens, are highlighted. Beginning January 14 and continuing daily throughout the year, visitors—equipped with a guidebook—will leave from a special "base camp" in the Hall of Asian Mammals to explore the Museum and learn about the historical and scientific significance behind the objects on display. An accompanying audioguide is available for a $5.00 fee. Children receive a special, illustrated "passport" featuring descriptions of twenty of the treasures. For information, call (212) 769-4552.

SEVEN YEARS IN THE LIFE OF A GRIZZLY

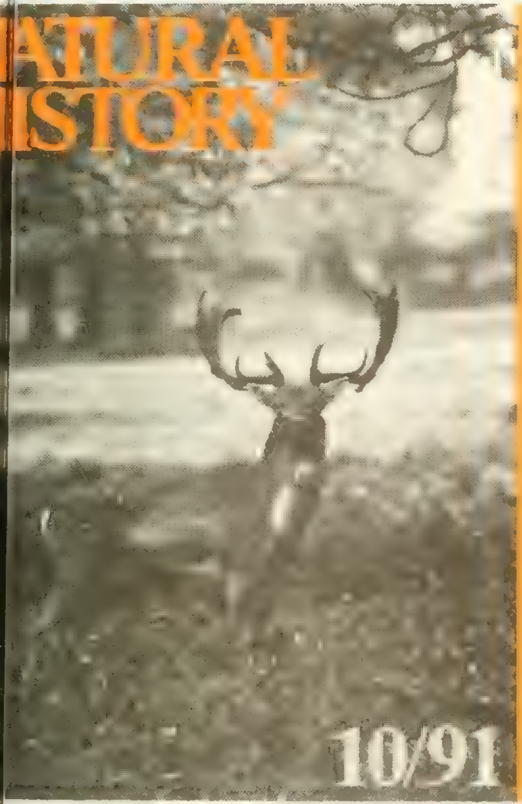
A grizzly bear clan in Alaska's Denali National Park will be the subject of a slide-illustrated talk on Thursday, January 19, by National Park Service ranger Rick McIntyre. For seven out of his fourteen summers in Denali, McIntyre has followed the life of Little Stony, from a playful cub to a full-grown adult. In telling the story of a grizzly and his family, as well as of the wolves, Dall's sheep, caribou, and moose in the park, McIntyre dramatizes the conflict be tween the rights of Denali's visitors to expe rience nature and the needs of wildlife t live unhampered by humans. The talk wi begin at 7:00 P.M. in the Kaufmann Theate Call (212) 769-5606 for ticket availability.

THE MONKEY WARS

The use of primates for scientific researc has generated intense debate for decades On Thursday, January 26, Deborah Blum, a science writer for the *Sacramento Bee,* wil talk about the various aspects of the contro versy that she investigated in her recentl published book, *The Monkey Wars,* base on a series of 1992 Pulitzer Prize-winnin articles. The lecture will begin at 7:00 P.M in the Kaufmann Theater. Call (212) 769 5606 for information and ticket availabilit

THE COCHIN JEWS OF INDIA

Ethnomusicologist Johanna Spector ha been documenting the history, material cul ture, and religious customs of the Jews o Cochin, who arrived on India's Malaba Coast as early as A.D. 72. By the time he first film, *About the Jews of India: Cochin* was completed in 1976, many of the 4,00 residents in Cochin had resettled in Israel Spector will talk about this prosperous, in fluential, and peaceful group on Tuesday January 31, at 7:00 P.M. in the Main Audito rium. Call (212) 769-5606 for ticket avail ability.



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STEROIDS AND THE HAZARD OF IMPACTS
On Monday, January 30, Clark Chapman,
enior scientist at Tucson's Planetary Sci-
nce Institute, will lecture on the reality and
nplications of asteroids colliding with the
arth. The slide-illustrated talk, part of the
eries "Frontiers in Astronomy and Astro-
hysics," will begin at 7:30 P.M. in the Hay-
en Planetarium's Sky Theater. Tickets are
8 ($6 for members). For information about
e Planetarium's Sky Show, *Update: The
niverse*, the exhibition "The Universe Re-
ealed: Recent Images from the Hubble
pace Telescope," and other Planetarium
vents, call (212) 769-5100.

NDIGENOUS PEOPLES CELEBRATION
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xamines cultural similarities and differ-
nces in New York City's communities. In
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hese events take place at the American
Museum of Natural History, Central Park
Vest at 79th Street in New York City. The
aufmann Theater is located in the Charles
. Dana Education Wing. The Museum has
pay-what-you-wish admission policy. For
ore information about the Museum, call
212) 769-5100.

Among the American Museum's art treasures are Joseph Wolf's watercolors, commissioned in the 1860s by zoologist Daniel Giraud Elliot, an early scientific adviser to the Museum. Selections from the Wolf collection, including an 1865 painting of Reeve's pheasants, left, will be on display at the entrance to the Hall of Mexico and Central America.

Beckett; AMNH

American Museum of Natural History

FAMILY ADVENTURES

VOYAGE TO LANDS OF GODS AND HEROES
JUNE 30 - JULY 11, 1995

The Mediterranean, steeped in history, culture and mythology, is one of the world's great treasure-troves of ancient sites and magnificent cities. The American Museum has designed a special family cruise for this coming summer - a program suited to parents, grandparents and children. Accompanied by Museum lecturers, participants will visit historic places in Italy, Greece and Turkey such as spectacular Santorini, Crete's famous Minoan town of Knossos, the acropolis at Lindos on Rhodes and the ancient sites of Ephesus and Olympia, as well as Istanbul and Athens.

WATERWAYS OF RUSSIA
JULY 15-26, 1995

Russia's two greatest cities, magnificent St. Petersburg and the capital city of Moscow, are linked by some of the most fascinating waterways in the world. This summer, a team of lecturers from the American Museum will lead a special cruise for families that want to immerse themselves in the culture of Russia. Along these waterways, participants will find a land of quaint villages, churches with onion-shaped copulas, palaces and spectacular scenery. And at either end are Russia's most important cities - centers for the art, architecture and culture for which this country are known.

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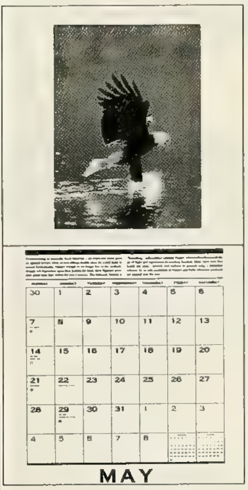

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AUTHORS

Nature photographer **Tui De Roy** (page 28) is shown here on the caldera floor of Fernandina Island. When she was two years old, her naturalist parents moved from Belgium to the Galápagos, where they discovered dozens of new species of mollusks and fishes. De Roy was schooled at home and began observing plants and animals at an early age, spending time in the company of visiting scientists. She published her first portfolio of photographs at the age of nineteen and became the first naturalist licensed by the Galápagos national park to introduce tourists to the region's wildlife. She now contributes scientific articles to volcanology journals. After thirty-five years in the Galápagos, De Roy recently moved to Golden Bay on New Zealand's South Island. Nonetheless, she writes, "I have come to regard the dynamic Fernandina volcano and its ever changing face as my spiritual home, where time and the modern world outside the caldera become irrelevant." Under her own imprint, she and her partner of twelve years, Mark Jones, recently produced *Portraits of Galápagos,* a book of photographs. For more on land iguanas, she recommends Dagmar Werner's chapter in *Iguanas of the World: Their Behavior, Ecology, and Conservation,* edited by A. Stanley Rand (Park Ridge: Noyes, 1983).

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"I always wanted to cross the Sahara," says **Paul C. Sereno** (page 40). "I had my first chance in 1990 and wound up at a magnificent dinosaur quarry." When he returned to excavate that graveyard three years later, Sereno and his crew got even more experience crossing deserts. His venture into the Sahara paid off with the discovery of two new species of 130-million-year-old dinosaurs, the first of their age to be found in Africa. Now an associate professor in the Department of Organismal Biology and Anatomy at the University of Chicago, Sereno received his doctorate in geological sciences from Columbia University while studying vertebrate paleontology at the American Museum of Natural History. In addition to his interest in the evolution of dinosaurs, he is currently using evidence from fossils and DNA sequences to learn more about the origins and early evolution of birds. Sereno recommends David Norman's *Illustrated Encyclopedia of Dinosaurs* (New York: Crescent Books, 1985) as the best general book on dinosaurs. For a comprehensive and more technical source, readers can turn to *The Dinosauria* (Berkeley: University of California Press, 1990), edited by David Weishampel, Peter Dodson, and Halszka Osmólska.

American Museum of Natural History

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June 14-27, 1995

The Danube, Europe's great "river of destiny," has been witness to centuries of human history under the Romans, Huns, Charlemagne, the Hapsburgs and many others. Weaving its way from the Black Forest to the Black Sea, it is a lifeline of trade along which some of Europe's most magnificent cities grew and flourished, leaving a rich legacy of art and architecture.

This spring, a team of lecturers from the American Museum will lead a cruise from Budapest to Nuremberg through Hungary, Austria and Germany. We will explore some of the great capitals of Europe - treasure-troves of magnificent Gothic, Renaissance, baroque and rococo architecture. Our route will also take us through the heartland of Europe, past rolling countryside dotted with lush vineyards, towering limestone cliffs, medieval villages, Roman ruins and ancient castles. Join us for an exciting voyage along this centuries-old trade route linking the great cities of Europe.

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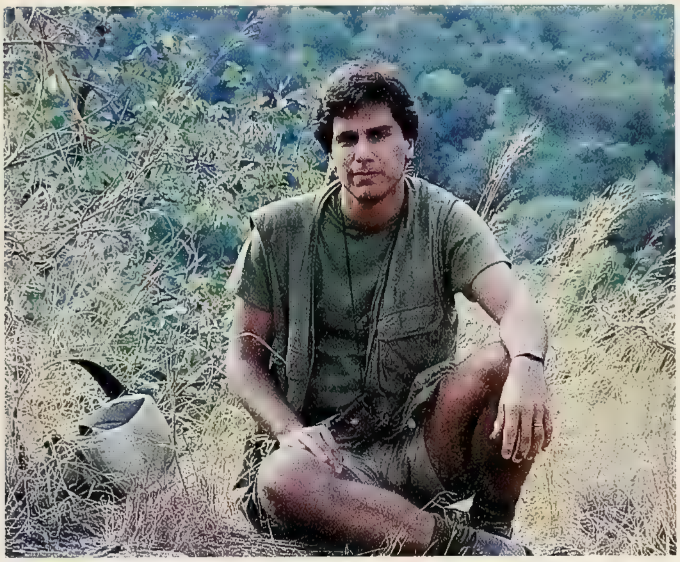
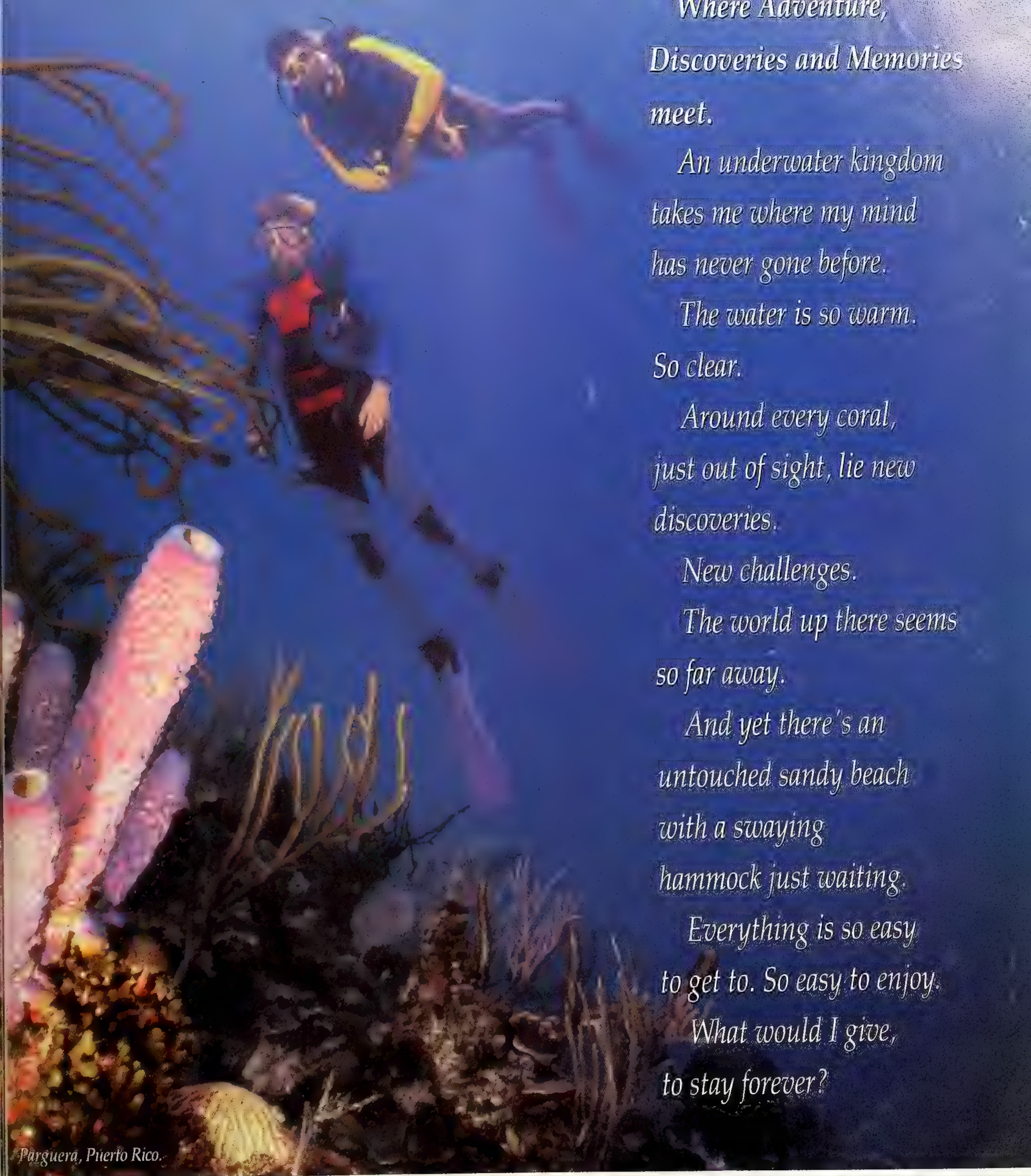


Craig B. Stanford (page 48) is an assistant professor of anthropology at the University of Southern California. His first fieldwork on primates was in Peru, where he studied tamarins. For his Ph.D. at the University of California, Berkeley, Stanford traveled to India and Bangladesh to investigate ecological influences on social behavior in capped langur monkeys. While working on the langurs, he was struck by how pressure from predators and the need to defend mates can sometimes explain primate social behavior better than more traditional explanations based on feeding ecology. The work at Gombe has been particularly poignant, with primate pitted against primate. Stanford hopes to expand his research to the evolution of hunting behavior in primates, including humans. His favorite primates, however, are not hunters at all: they are his two small daughters, who sometimes accompany him into the field. For more on hunting primates, Stanford suggests Geza Teleki's *The Predatory Behavior of Wild Chimpanzees* (Lewisburg: Bucknell University Press, 1973). *The Chimpanzees of Gombe,* by Jane Goodall (Cambridge: Harvard University Press, 1986), provides a thorough and intimate look into the lives of these close relatives of ours.

Fred Bruemmer (page 56) has traveled extensively in the Arctic for thirty-seven years, living for many months at a time with Inuit in their camps. Some of the people he met still had knowledge of Inuit life in precontact times. From them he learned many details about traditional hunting techniques, including the use of *inukshuit,* or stone men, in caribou drives. A longtime contributor to *Natural History* (this is his twenty-third article), Bruemmer most recently wrote about sea lions in the September 1994 issue ("Rough Rookeries"). He is also the author of two recent books, *The Narwhal: Unicorn of the Arctic Sea* and *Arctic Memories: Living with the Inuit,* both published by Key Porter Books, Toronto. For additional reading, he recommends *Prehistory of the Eastern Arctic,* by Moreau S. Maxwell (Orlando: Academic Press, 1985).

Craig Brandt (page 78) has enjoyed photography since he was nine. "My mother, who was a fine photographer in her own right, sparked my interest in photography when she gave me my first camera, a plastic Kodak Brownie, in the mid-1960s. I still have the first photograph I ever took—a picture of my older brother sitting on the couch with a smirk on his face because he didn't think there was any film in the camera." Brandt grew up in Los Angeles, but frequent trips with his parents to the Sierras and other parts of the West gave him a lasting desire to get away from it all. In 1976 he received an associate of arts degree in forestry, but when he realized that his bank account and his college goals were incompatible, he decided on an apprenticeship in heavy equipment mechanics—a skill he could take anywhere. In 1983, he married his wife, Robin, whom he had met in a mountaineering course. For their honeymoon, they packed up their stuff and went to Fairbanks, Alaska. They never left. Brandt now lives in McKinley Village, a small town just outside Denali National Park. When not wielding a wrench, he enjoys canoeing and hiking with his wife, who also enjoys photography. In Denali, they find no shortage of wildlife to photograph. The shot of the Dall's sheep rams in this issue was taken with a Pentax 645 camera and a 600 mm f5.6 lens.



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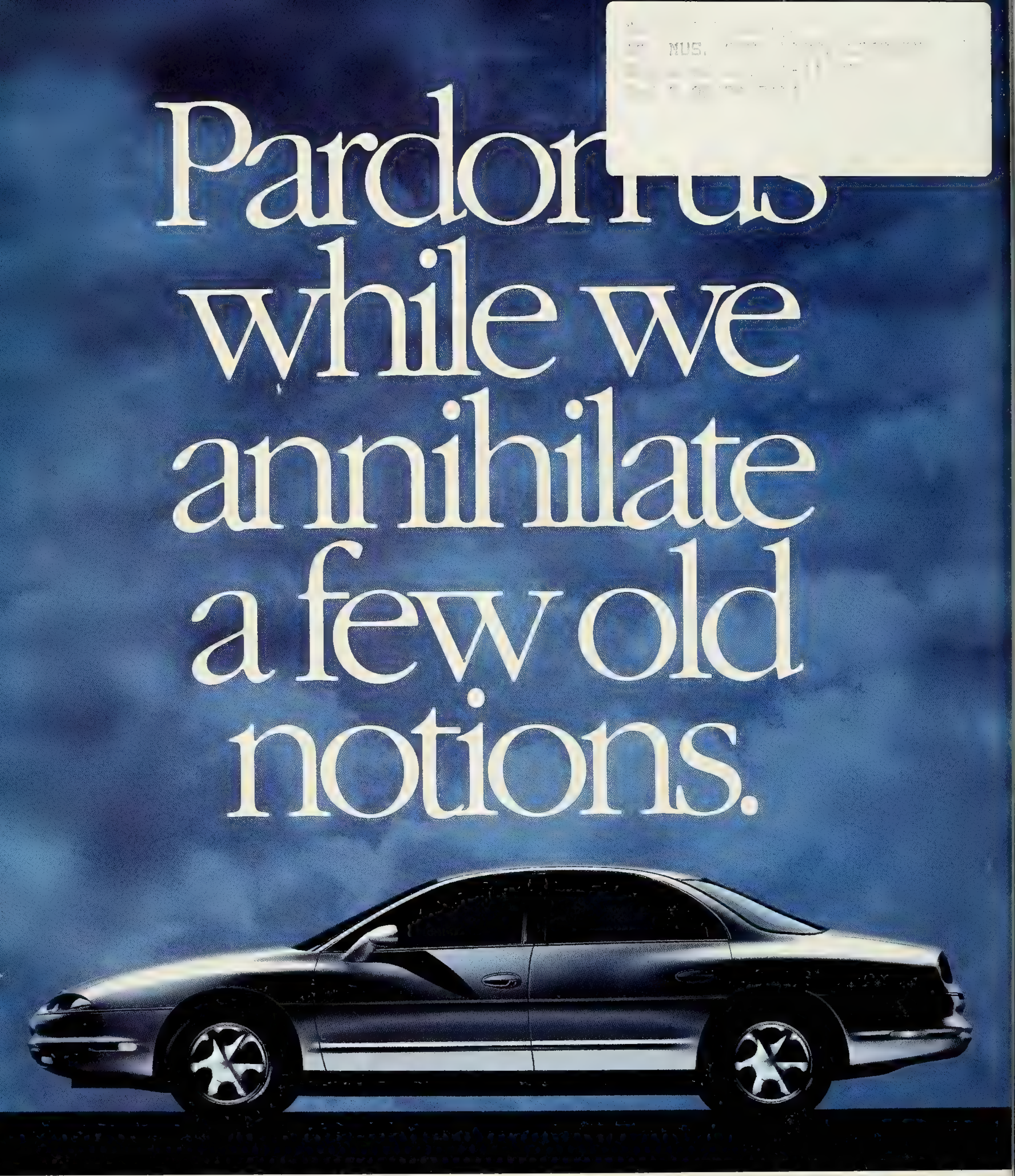

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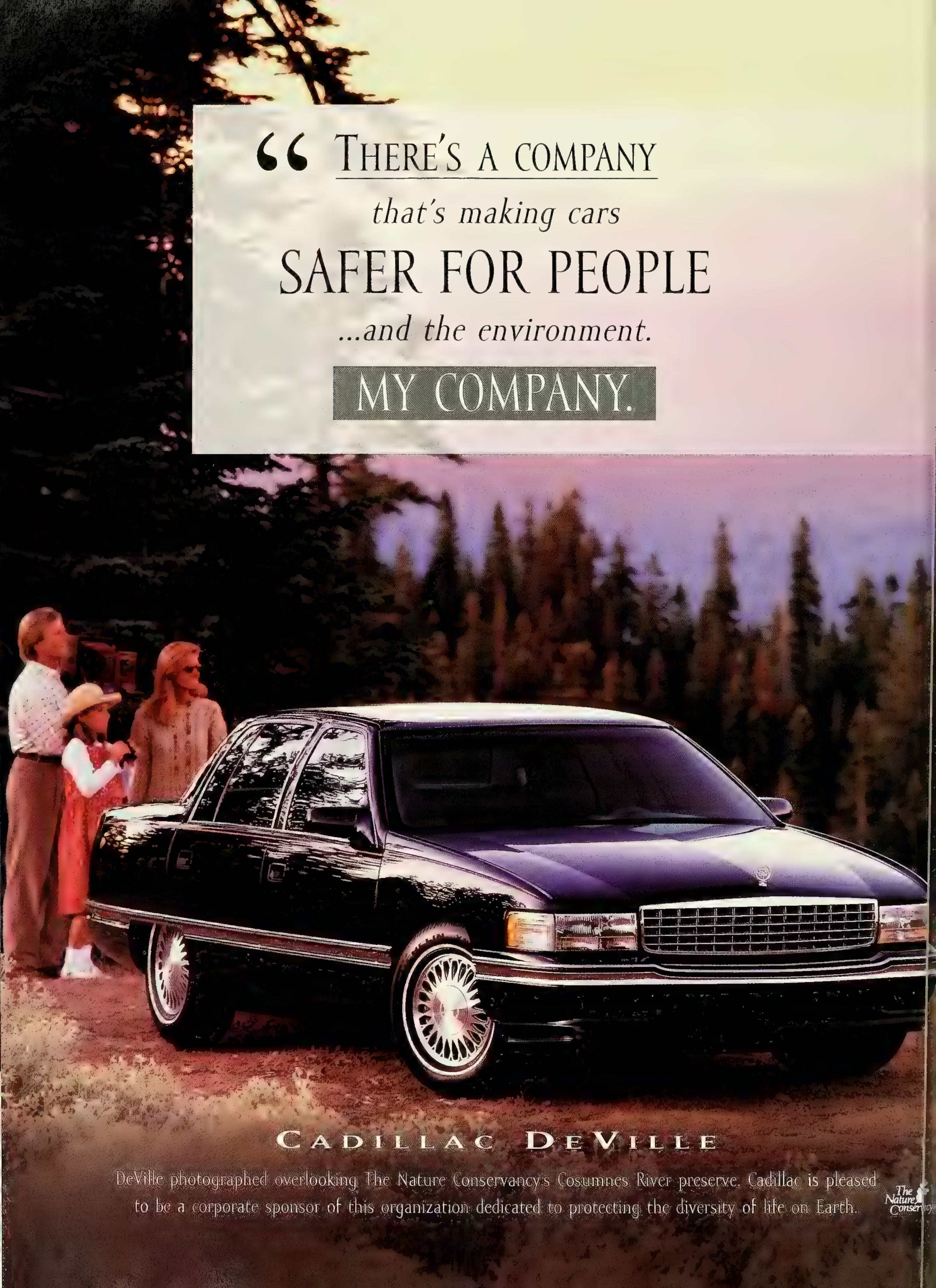
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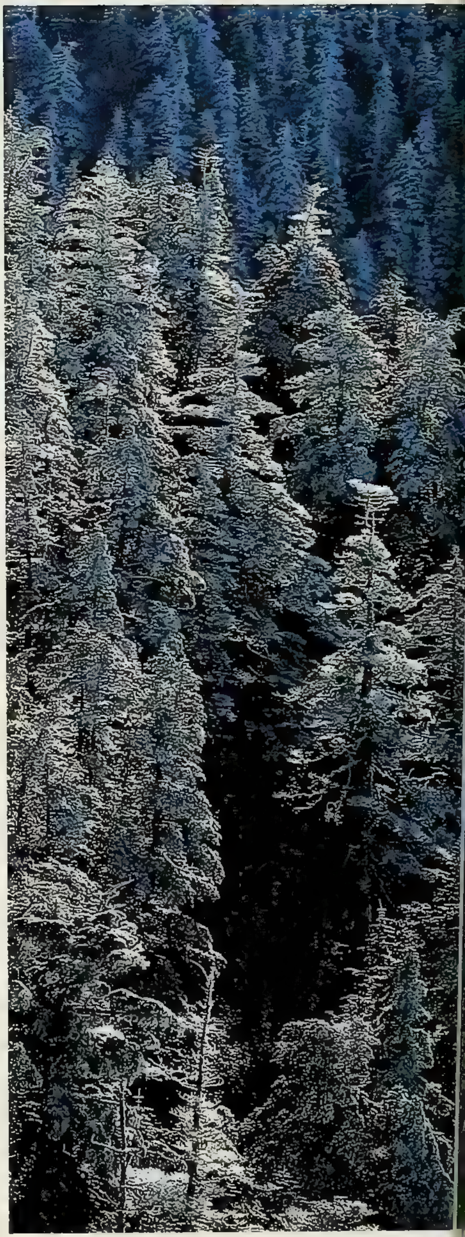

COVER: Aiguille Saint Exupéry, a granite pillar in Patagonia, is one of the Andes' more stunning peaks. With new ways of observing Earth's interior dynamics, geophysicists have revised their notion of how these mountains—and many other of the planet's features—were formed. Story on page 52. *Photograph by Galen Rowell; Peter Arnold, Inc.*

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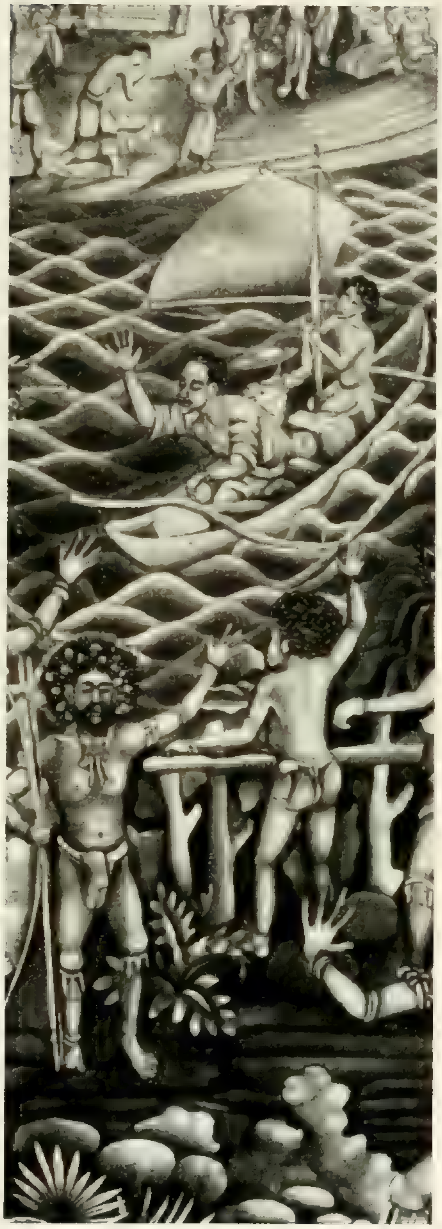

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Flying Lessons from a Flightless Insect

Can winter stoneflies teach us how insects first took to the air?

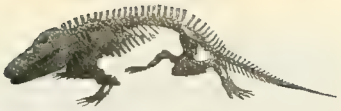
by James H. Marden

By late February of 1994, the sunshine finally carried enough warmth to nudge the midday temperature a few degrees above freezing. After a seemingly interminable succession of severe storms and record snowfalls, the brutal winter was finally drawing to an end. With the promise of spring in the air, my student Melissa Kramer and I trudged through thigh-deep snow to reach the shores of Bald Eagle Creek in central Pennsylvania. We had come to collect winter stoneflies, some of the first adult insects to appear each year in this part of the world. These stoneflies, *Taeniopteryx burksi,* spend a year living as herbivorous nymphs in the streams where they were born. Once they are fully mature (in February or March), the nymphs metamorphose into their flightless, adult form, leave the water, and crawl about on streamside snow in search of mates.

The stoneflies' ability to complete their life cycle at cold temperatures is unusual among insects, but it was not the reason we had ventured out through the snow. We had come to see if these little-studied insects might shed light on an event that occurred some 350 million years ago, one that forever changed the way life evolved on Earth: the evolution of insect flight. When insects took to the air, they became capable of traveling over land faster and farther than any life forms that preceded them and of colonizing remote patches of habitat. Flight allowed novel ways of interacting with the environment, which in turn led to faster evolution and frequent speciation. The end result is that flying insects are the most speciose life form on the planet (roughly 60 percent of all living species described by science). Robin Wootton, of the University of Exeter in the United Kingdom, has written that humans must deal daily with the consequences of

Winged but flightless, an adult winter stonefly walks about on streamside ice and snow in search of a mate.

Photographs by James H. Marden



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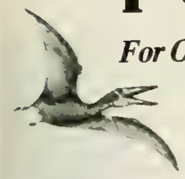

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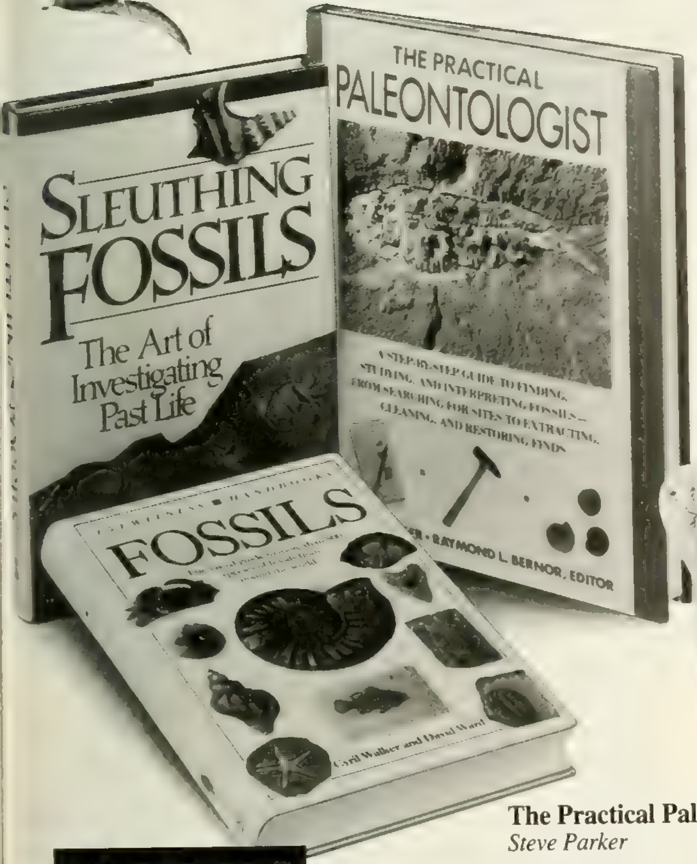

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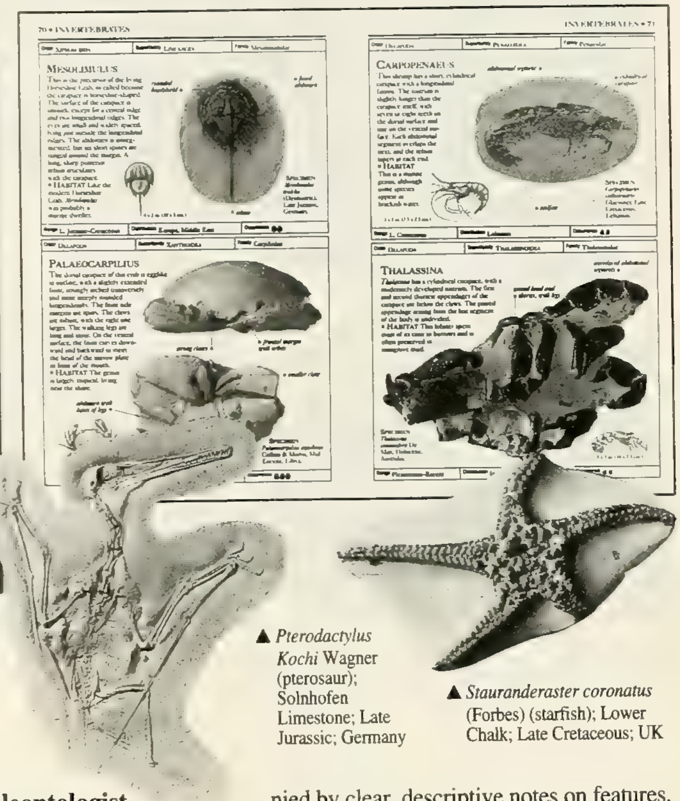

▲ *Pterodactylus Kochi* Wagner (pterosaur); Solnhofen Limestone; Late Jurassic; Germany

▲ *Stauranderaster coronatus* (Forbes) (starfish); Lower Chalk; Late Cretaceous; UK

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Swiftly moving water is no barrier to winter stoneflies, which use their wings to skim across the surface to reach the shore.

this profound evolutionary event, a statement I am reminded of every time I swat at mosquitoes biting my ankles or see a farmer spraying pesticides on a field.

But in late February there were no mosquitoes, just a few stoneflies walking around on the snow. What could these drab insects possibly teach us about the evolution of insect flight? The answer to that question goes back to 1985, when I read a paper by Joel Kingsolver and Mimi Koehl, of the University of California, Berkeley, that addressed a long-standing mystery in evolution. How could insects have evolved wings long enough to confer aerodynamic benefits (for example, the ability to glide some nontrivial distance) when initial increases in the size of any protowings would probably not have been advantageous and thus would not have given natural selection anything to act on?

Kingsolver and Koehl proposed that the ancestors of flying insects could have used tiny protowings on the thorax (the middle of an insect's three body regions) to warm themselves and thus walk faster and cover more ground. Their experiments with artificial insect models indicated that larger winglets resulted in higher body temperatures. At a certain wing size, they argued, selection for aerodynamic benefits, rather than thermoregulation, could have taken over as the driving force behind the evolution of wings.

This study received widespread attention, and colleagues told me that the problem was now solved, with no reason to study it any further (*see* "Not Necessarily a Wing," by Stephen Jay Gould, *Natural History,* October 1985). I remained skeptical, however, because the Kingsolver and Koehl model did not address how natural selection produced the muscles, movable wing joints, and complex neuromotor coordination that are just as necessary for effective flapping flight as large wings. I could not imagine how a nonflying or gliding insect could benefit from rudimentary versions of these features. Flight requires the simultaneous function of a suite of interdependent anatomical and behavioral traits; long wings are but one part of the puzzle. Furthermore, Kingsolver and Koehl performed their experiments with physical models rather than real insects, yet as Bernd Heinrich, of the University of Vermont, has pointed out, the most primitive extant winged insects (mayflies an stoneflies) are not known to engage in an form of thermoregulation.

Another key part of many evolutionar puzzles is the fossil record. Unfortunatel there are no fossil remains of the earlie flying insects, but the existing evidenc suggests that flying insects may hav evolved from aquatic ancestors that swa and/or moved water over their gills b flapping movable gill plates on the thora and abdomen. Jarmila Kukalova-Peck, Carleton University in Ontario, has lon championed the idea that insect win arose from movable gills, drawing suppo for her hypothesis from development anatomical, and neurological homologi between wings and the gill plates of fos and living insects. This conclusion h been met with some skepticism, partly b cause it is difficult to picture how aquatic insect could evolve into a flyi one without losing its gill plates during t intervening terrestrial stage.

To my way of thinking, howev Kukalova-Peck's interpretation is the m convincing offered to date. And gill pl

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origins would solve the even more daunting problem of how the complex joints, muscles, and neuromotor coordination needed for flapping flight evolved. If these features were already in place because ancestral insects flapped their gill plates, then all of the essential elements of a flight motor would have already existed. In that case, the problem could be reduced to figuring out where and how the transition from water to air occurred, a puzzle that gnawed at me for a number of years.

My father introduced me to fly-fishing in my early teens, so I had been an observer of aquatic insects periodically throughout my adult life. However, observing animals casually and watching them in detail are two very different things, and thus I began in 1985 to watch aquatic insects with a newfound intensity. What I began to appreciate was that adult forms of many aquatic insects spend a great deal of time moving about on the water surface, and they do so in a wide variety of ways. Whirligig beetles swim about in frenetic groups like crazed little motorboats; water striders stroke gracefully along like oarsmen; caddis flies paddle frantically with their hind and middle legs, periodically rising off the surface to fly for a few feet, only to settle back upon the water. Anyone sitting beside a lake or stream on a warm summer evening can observe dozens of other such examples.

The advantage of traveling on the water's surface rather than beneath it lies in the hundredfold decrease in density and viscosity as one goes from water to air. Small aquatic animals that manage to rise up onto the water surface can move about much more rapidly than can subsurface swimmers. Thrust is still required, of course, and can be supplied for surface travel by either a hydrodynamic (water-moving) or an aerodynamic (air-moving) mechanism. Evolutionary transitions between these two types of mechanisms are fairly common, for hydrodynamic devices typically make passable aerodynamic devices (picture a boat propeller being used as a fan). Various animals, such as flying fish and penguins, have made the transition, and some birds, such as puffins, use their wings for both swimming and flying.

This line of thought suggested that the water surface was the "where" piece of my puzzle, but I was still looking for an answer to the "how" question. Then, in February of 1991, while teaching an ecology course that required students to collect a sample of aquatic insect nymphs from a stream in central New York State, I had a revelation. While the chilled students labored to collect nymphs from the bottom sediments, I was surprised to find that adult stoneflies were walking about on streamside snowbanks. What really caught my attention was how these insects managed to reach the snowbanks, for many of them were emerging from their nymphal stage in midstream, on bits of plants, rocks, or ice protruding out of the water. To reach shore—often fifteen to thirty feet away across fast-flowing water — they traveled atop the water surface in much the same way as an Everglades airboat, with aerodynamic thrust supplied by beating wings. The arc of the wingstroke was cut short by the water beneath the body but was otherwise indiscernible from that of a flying insect. All six legs maintained continuous contact with the water. In this fashion, the stoneflies skimmed steadily along the surface, moving many times faster than they could have by walking or swimming underwater. When I tossed these stoneflies into the air, they flapped feebly while plummeting to the ground, thus demonstrating that they cannot fly at typical environmental temperatures (although they can fly weakly in the lab at room temperature). Now the puzzle pieces were falling into place, for here was a primitive insect that could not fly, but was using an aerodynamically powered form of semiaquatic locomotion. Might this behavior represent a viable intermediate stage for the transition between swimmers and fliers?

To answer this question, Melissa and I set out to determine how surface-skimming ability varied with changes in wing size, flight muscle size, and muscle power. In particular, we needed to know if even stoneflies with very small wings and low muscle power (characteristics presumably possessed by ancestral insects that first attempted aerodynamically powered surface skimming) are able to skim faster than they can swim. We also needed to determine if small increments in wing size and muscle power cause steady improvements in skimming performance.

To produce wings of varying sizes, we simply trimmed the stoneflies' wings with scissors. We varied muscle power by reducing the temperature, since cold muscles contract more slowly and thus generate considerably less power. Experiments that Melissa and I conducted during February and March of 1994 showed that under optimal conditions, surface-skimming stoneflies could reach speeds of about one and a half feet per second, and that skimming velocity exceeded top swimming speed even when we reduced their wings to small flaps (25 to 30 percent of their original length and area, a size comparable to that of the gill flaps of fossil insects) and subjected them to temperatures as low as 35° F, when muscle power output is minimal. As temperature and wing size were increased, surface-skimming velocity improved steadily. These results supported our hypothesis: surface skimming, even with a rudimentary flight motor, is an improvement over swimming, and gradual selection for faster surface skimmers could result in the evolution of large wings and muscles.

While these experiments are valuable as a demonstration of what is mechanically possible and evolutionarily feasible, we don't know yet whether surface skimming in our stoneflies, *Taeniopteryx burksi,* is an ancient behavior that might date back to the very roots of insect flight or has evolved from strong-flying ancestors. The loss-of-flight scenario would be easy to infer if all of the close relatives of *Taeniopteryx* were strong fliers; however, the entire Nemouroidea superfamily contains only a few species, belonging to a single family, that are known to be strong fliers. (The remainder of this superfamily, which appears to have originated early on in the evolution of stoneflies, are all either surface skimmers or their locomotion has not yet been studied.)

At present, we are examining features of wing vein structure that appear to correlate with flight ability in stoneflies. If vein structure can be used as a reliable indicator of flight ability, then we will be able to make broad surveys of museum specimens and perhaps even fossils to determine how flight ability has changed during the evolution of stoneflies and primitive insects in general. Such analyses, however, are inevitably difficult and imprecise. They depend heavily on certain untestable assumptions and the principle of parsimony; that is, the need to decide which among competing historical scenarios would have required the fewest evolutionary transitions. Thus, we may never know for sure how flight evolved in stoneflies, but the research is exhilarating nonetheless, for when we look at surface-skimming stoneflies in the present, we may be peeking a third of a billion years into the past.

Jim Marden is an assistant professor of biology at Pennsylvania State University University Park.

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CHEWAN

Ghosts of Bell Curves Past

The mismeasure of man continues, as a current bestseller revives academic racism's old arguments

Stephen Jay Gould

I don't know whether or not most white men can jump (although I can attest, through long observation, that Larry Bird cannot—but, oh Lord, could he play basketball!). And I don't much care, although I suppose that the subject bears some interest and marginal legitimacy in an alternate framing that avoids such biologically meaningless categories as white and black. Yet I can never give a speech on the subject of human diversity without attracting some variant of this inquiry in the subsequent question period. I hear the "sports version," I suppose, as an acceptable surrogate for what really troubles people of good will (and bad, although for other reasons).

The old days of overt racism did not engender such squeamishness. When the grandfather of modern academic racism, Joseph-Arthur, comte de Gobineau (1816–82), asked a similar question about the nature of supposedly inborn and unchangeable differences among racial groups, he laid it right on the line. The title of the concluding chapter to volume one of his most influential work, *Essai sur l'inégalité des races humaines* (Essay on the Inequality of Human Races), reads: "Moral and Intellectual Characteristics of the Three Great Varieties." Our concerns have always focused on smarts and decency, not jumping height and susceptibility to cardiovascular arrest.

And Gobineau left no doubt about his position:

> The idea of an innate and permanent difference in the moral and mental endowments of the various groups of the human species, is one of the most ancient, as well as universally adopted, opinions. With few exceptions, and these mostly in our own times, it has formed the basis of almost all political theories, and has been the fundamental maxim of government of every nation, great or small. The prejudices of country have no other cause; each nation believes in its own superiority over its neighbors, and very often different parts of the same nation regard each other with contempt.

Gobineau was undoubtedly the most influential academic racist of the nineteenth century. His writings strongly affected such intellectuals as Wagner and Nietzsche and inspired a social movement known as Gobinism. Largely through his influence on the English zealot Houston Stewart Chamberlain, Gobineau's ideas served as a foundation for the racial theories espoused by Adolf Hitler. Gobineau, an aristocratic royalist by background, interspersed writing with a successful diplomatic career for the French government. He wrote several novels and works of historical nonfiction (a history of the Persian people and of the European Renaissance, for example), but became most famous for his four-volume work on racial inequality, published between 1853 and 1855.

Gobineau's basic position can be easily summarized: the fate of civilizations is largely determined by racial composition, with decline and fall usually attributable to dilution of pure stocks by interbreeding. (Gobineau feared that the contemporary weakening of France, largely to German advantage, could be "traced to the great variety of incongruous ethnical elements composing the population," as his translator wrote in introducing the first American edition of 1856.) The white races (especially the dominant Aryan subgroups) might remain in command, Gobineau hoped, but only if they could be kept relatively free from miscegenation with intellectually and morally inferior stocks of yellows and blacks (Gobineau used these crude terms of color for his three major groups).

No one would doubt the political potency of such ideas, and no one would credit any claim that Gobineau wrote only in the interest of abstract truth and with no agenda of advocacy in mind. Nonetheless, it does no harm to point out that the American translation, published in Philadelphia in 1856, as Dred Scott stood before the Supreme Court near the brink of our Civil War, surely touched a nerve in parlous times—for Gobineau's distinctive notion of racial purity, and the danger of intermixing, surely struck home most strongly in our nation of maximal racial diversity and pervasive inequality, with enslavement of blacks and decimation of Indians. J. C. Nott of Mobile, America's most active popularizer of anthropology in the racist mode, wrote a long appendix to the translation (his textbook, *Types of Mankind*, written in 1854 with G. R. Gliddon, was the contemporary American bestseller in the field). Lest anyone miss the point of local relevance for this European treatise, the translator wrote in his preface:

> The aim [of studying racial differences] is certainly a noble one, and its pursuit cannot be otherwise than instructive to the statesman and historian, and no less so to the general reader. In this country, it is particularly interesting and important, for not only is our immense territory the abode of the three best defined varieties of the human species—the white, the negro, and the Indian—to which the extensive immigration of the Chinese on our Pacific coast is rapidly adding a fourth, but the fusion of diverse nationalities is nowhere more rapid and complete.

Yet Gobineau needed evidence for his

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* False. The *Dimetrodon* was actually an early relative of mammals that lived in North America some 280 million years ago.

claims. (Note that my previous quotation from Gobineau's book only asserts a belief of all people in innate inequality, not any evidence that this common impression is correct.) Therefore, in the last chapter of his work, Gobineau outlines an approach to securing this necessary data for his racism. He begins by telling us how we should *not* frame the argument. We should not, he claims, point to the poor accomplishments of individuals in "inferior races," for such a strategy will just backfire as egalitarians search for rare exemplars of high achievement within generally benighted groups. Gobineau begins his final chapter by writing (the quotation is long, and chilling, but well worth the space for its reminder about "certainties" of a not so distant past):

> In the preceding pages, I have endeavored to show that . . . the various branches of the human family are distinguished by permanent and ineradicable differences, both mentally and physically. They are unequal in intellectual capacity, in personal beauty, and in physical strength. . . . In coming to this conclusion, I have totally eschewed the method which is, unfortunately for the cause of science, too often resorted to by the ethnologists, and which, to say the least of it, is simply ridiculous. The discussion has not rested upon the moral and intellectual worth of isolated individuals.
>
> I shall not even wait for the vindicators of the absolute equality of all races, to adduce to me such and such a passage in some missionary's or navigator's journal, wherefrom it appears that some Yolof has become a skillful carpenter, that some Hottentot has made an excellent domestic, that some Caffre plays well on the violin, or that some Bambarra has made very respectable progress in arithmetic.
>
> I am prepared to admit—and to admit without proof—anything of that sort, however remarkable, that may be related of the most degraded savages. . . . Nay, I go farther than my opponents, and am not in the least disposed to doubt that, among the chiefs of the rude negroes of Africa, there could be found a considerable number of active and vigorous minds, greatly surpassing in fertility of ideas and mental resources, the average of our peasantry, and even of some of our middle classes.

(Pervasiveness of prejudice does reside in the unconscious details. Note how Gobineau, writing in his self-styled generous mode, still cannot imagine, for an African ruler, any higher intellectual status than the European peasantry, or just perhaps the lower reaches of the bourgeoisie—but never, heaven forfend, even the worst of the upper classes!)

Convergent Evolution

"Really? I'm divorced and have three children too!"

How, then, shall racial status be affirmed if arguments about individuals have no validity? Gobineau states that we must find a measure, preferably imbued with the prestige of mathematics, for average properties of groups:

> Once for all, such arguments [about individuals] seem to me unworthy of real science. . . . Let us leave such puerilities, and compare, not the individuals, but the masses. . . . This difficult and delicate task cannot be accomplished until the relative position of the whole mass of each race shall have been nicely, and, so to say, mathematically defined.

I was, I confess, prompted to reread Gobineau by the current brouhaha over *The Bell Curve,* by Charles Murray and my late colleague Richard Herrnstein, for I recognized that they use exactly the same structure of argument about individuals and groups, although for quite a different purpose, and the disparity within the similarity struck me as eerie. Herrnstein and Murray also claim that average differences in intelligence between racial groups are real and salient (also largely innate and effectively immutable), and they also insist that such group disparities carry no implication for the judgment of individuals. In this way, they hope to avoid a charge of racism and secure a judgment as upholders of human rights, for no black individual, in their view, should be devalued because his group is innately less intelligent than whites; after all, this particular individual may be a rarely brilliant member of his averagely dumb race. (I must say that I regard such an argument as either disingenuous or naïve, and I can't view Mr. Murray as naïve, given the realities of racial attitudes in America versus our ideal hopes for judgment of all individuals on their personal achievements and attributes alone, and not by their group membership.)

Gobineau wished to separate individual and group judgment because he didn't want the "reality" of group differences blurred by the uncharacteristic performance of rare individuals. Herrnstein and Murray make the distinction in a very different political climate; they emphasize the *reality* of individual achievement (rather than its annoying confusion) in order to avoid (and fairly enough) the charge of racism, while maintaining something quite close to Gobineau's atti-

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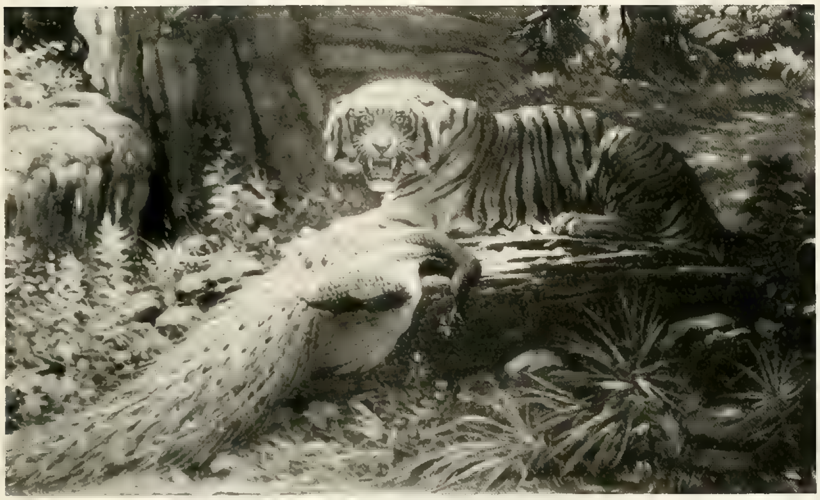

CHARLES R. KNIGHT, OIL ON CANVAS, 60" x 44", 1928

A celebration of the animal in art will be taking place at New York City's Wallace Hall (Park Avenue at 83rd Street) this coming March in the first major auction on the North American continent devoted to this joyous art form. Many hundreds of original paintings, pieces of sculpture, rare prints and artifacts incorporating the animal in their design will be sold over two unprecedented days. The sale will be divided into sections based on vintage and contemporary wildlife art and animal-related artifacts including folk art, (weathervanes, decoys, textiles, etc.) and a magnificent section devoted to vintage carousel figures. Guernsey's would like to point out that taxidermied figures and objects produced from the slaughter of animals will not be included and that a portion of the works will be sold in support of several leading animal preservation societies.

The range of work offered is formidable. Audubon, Thornburn, Stubbs, Gould, Fuertes and Bull are just a sampling of the greats from the past represented. Significantly, nine major works by the legendary turn-of-the-century muralist Charles R. Knight (American Museum of Natural History, The Field Museum, The Smithsonian) will be featured. Importantly, the section devoted to contemporary wildlife art may well be the finest assemblage to date of work by the truly great living artists of the world. A veritable "hall of fame" (Bateman, Coheleach, Shepherd, Brenders, Kuhn, Eckelberry, Lansdowne and Ostermiller are just a small sampling), the collection will be stunning.

The entire event will be documented in a fully illustrated, approximately 300 page catalogue that will serve as admission to the event and permit absentee bidding for those unable to attend in person.. To receive the catalogue, kindly send a check to Guernsey's for $40 within the U.S., $45 to Canada and $60 internationally. To order by phone, discuss the possibility of late consignment or simply have questions, please contact us. At Guernsey's, we're thrilled to be part of this landmark event and we very much hope you'll agree that this indeed is an auction not to be missed.

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tude about group differences in intelligence and the unlikelihood of their erasure. (Please understand that I am not trying to besmirch Herrnstein and Murray by name-calling from the past. I am not attempting to establish any indirect linkage to the Third Reich—and neither can we blame Gobineau for Hitler's extreme usages via Chamberlain. But I do find it fascinating that structures of ideas can be so similar across the centuries, while thinkers of basically consonant mind will emphasize different parts of an entity in the climates of varying times.)

Gobineau, seeking his mathematical basis for group differences in intelligence and morality, was stuck with the crude and direct measures of nineteenth-century racist science—mainly shapes and sizes of skulls and other body parts (for no supposedly "direct" assessment by mental testing had yet been developed). For example, Gobineau located black destiny in external anatomy:

> The dark races are the lowest on the scale. The shape of the pelvis has a character of animalism, which is imprinted on the individuals of that race ere their birth, and seems to portend their destiny. . . . The negro's narrow and receding forehead seems to mark him as inferior in reasoning capacity.

Moreover, in a manner so characteristic of this pseudoscience, Gobineau manages to spin every observation in the light of his preconception about black inferiority. Even ostensibly favorable traits get redeployed in the service of racist interpretation. On the supposed stoicism of blacks in the face of pain, for example, Gobineau cites the testimony of a doctor: "They bear surgical operations much better than white people, and what would be the cause of insupportive pain to a white man, a negro would almost disregard. I have amputated the legs of many negroes, who have held the upper part of the limb themselves." Any white man would be praised for bravery, courage, and nobility, but Gobineau attributes this supposed toleration of pain by blacks to "a moral cowardice which readily seeks refuge in death, or in a sort of monstrous impassivity."

As measurement of bodies formed the crude and only marginally successful (even in their own terms) devices of scientific racism in the nineteenth century, so has the more sophisticated technology of mental testing—measuring the subtle inside, as it were, rather than the indirect outside—set the basis for most arguments about human inequality in the twentieth century. (As I explain in much greater detail in my book *The Mismeasure of Man,* I am not opposed to all forms of mental testing and I certainly do not view the enterprise as inherently racist or devoted to arguing for immutable human differences—for exactly the opposite intention has often been promoted in using tests to measure the improvement that good education can supply.)

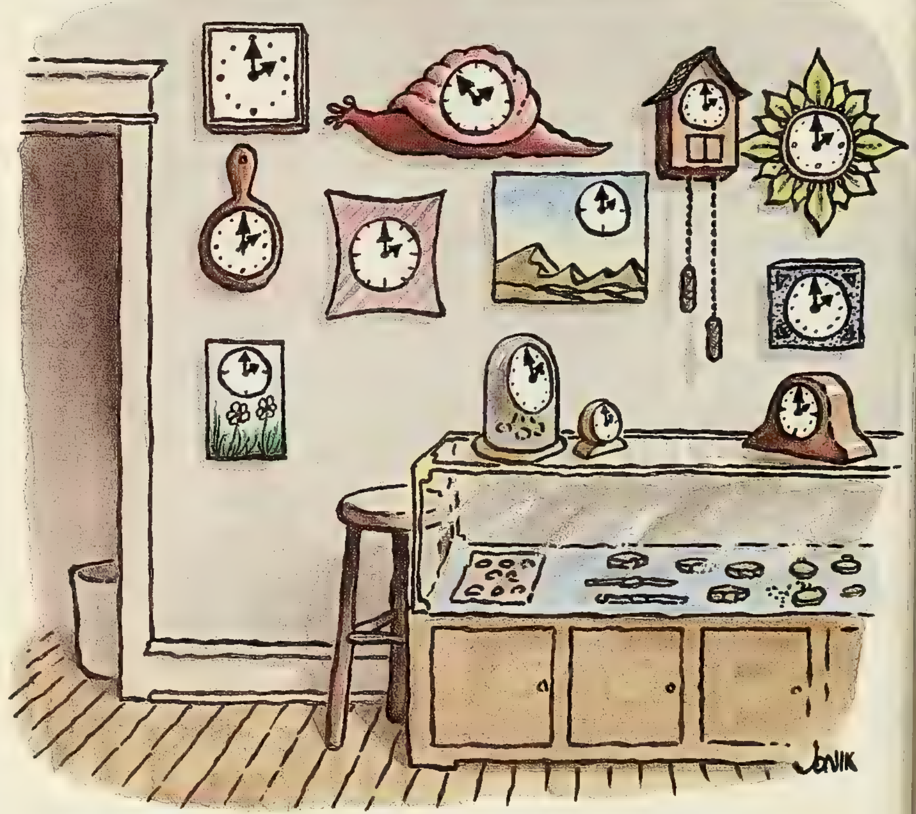
Nevertheless, one particular philosophy of mental testing does undergird most arguments about intellectual differences among human groups made in our century. Moreover, this philosophy does emerge directly from the cruder techniques of body measurement that defined the subject in the nineteenth century—and in this sense, we may trace continuity from Gobineau to this particular hereditarian theory of IQ. I thought that this philosophy had receded from influence as a joint result of well-exposed fallacies in the general argument and failure of data to validate the essential premises. But Herrnstein and Murray have revived this philosophy in its full and original form in *The Bell Curve,* and we must therefore return to the historical sources of fallacy.

The "Gobinist" version of mental testing—use of the enterprise to argue for innate and ineradicable differences in general intelligence among human groups—relies upon four sequential and interrelated premises; each must be true individually (and all the linkages must hold as well) or else the entire edifice collapses:

1. The wonderfully multifarious and multidimensional set of human attributes that we call intelligence in the vernacular must all rest upon a single, overarching (or undergirding) factor of general intellectual capacity, usually called *g,* or the general factor of intelligence (see my critique of this notion and its mathematical basis in chapter 6 of *The Mismeasure of Man*).

2. The general "amount" of intelligence in each person must be abstractable as a single number (usually called IQ). A linear ranking of people by IQ must therefore establish a hierarchy of differential intelligence. And, finally (for the social factor in the argument), people's achievements in life, and their social ranks in hierarchies of worth and wealth, must be strongly correlated with their IQ scores.

3. This single number must measure an



inborn quality of genetic constitution, highly heritable across generations.

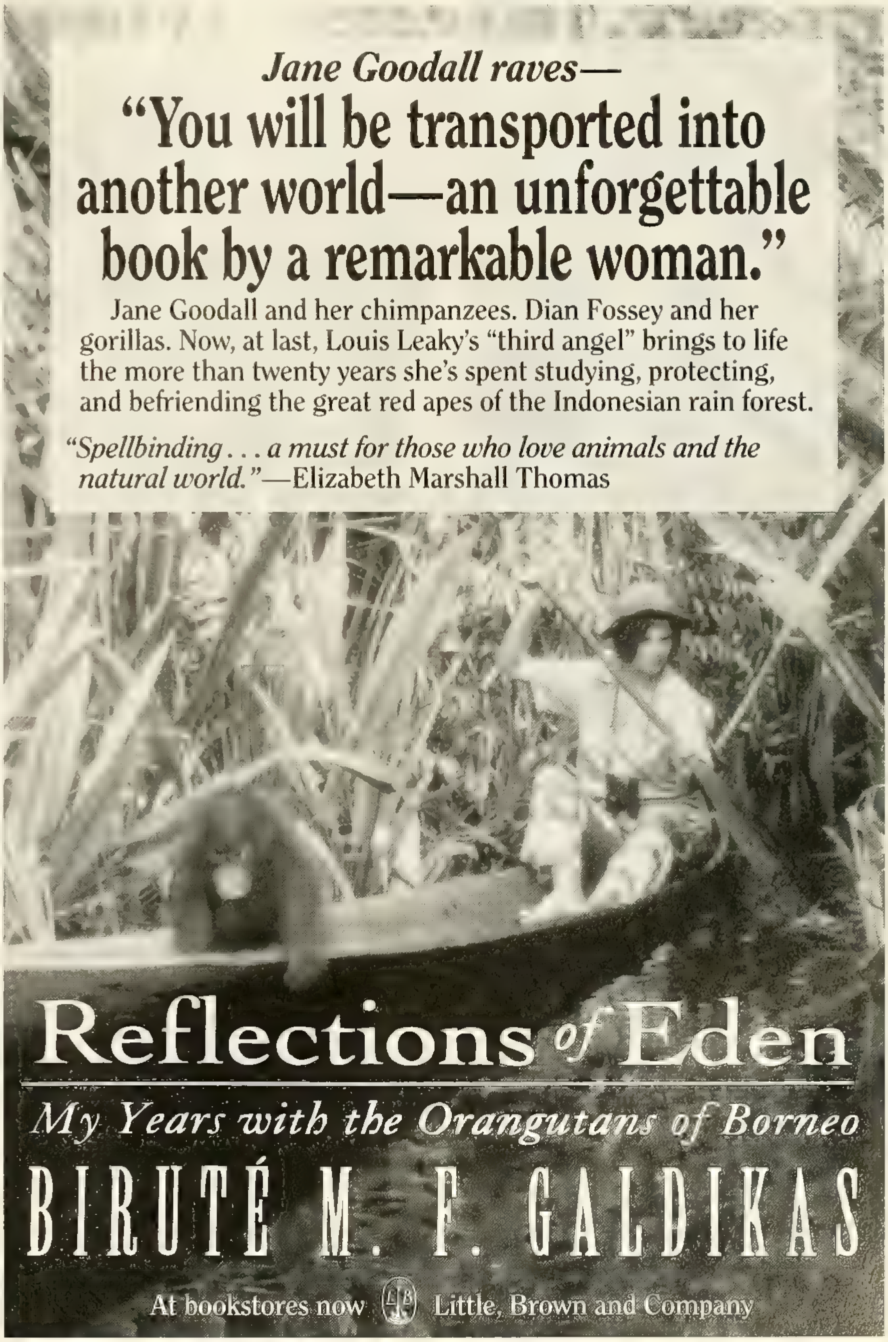
4. A person's IQ score must be stable and permanent—subject to little change (only minor and temporary tinkering) by any program of social and educational intervention.

In other words, to characterize each of the four arguments in a word or two, human intelligence must be abstractable (as a single number), rankable, highly heritable, and effectively immutable. If any of these assumptions fails, the entire argument and associated political agenda goes belly-up. For example, if only the fourth premise of immutability is false, then social programs of intense educational remediation may well boost, substantially and permanently, an innate and highly heritable disadvantage in IQ—just as I may purchase a pair of eyeglasses to correct an entirely inborn and fully heritable defect of vision. (The false equation of "heritable" with "permanent" or "unchangeable" has long acted as a cardinal misconception in this debate.)

I cannot, in this essay, present a full critique of *The Bell Curve* (see my review in *The New Yorker* for November 28, 1994). I only wish to trace some historical roots and to expose a stunning irony. The form of argument about average intelligence among racial groups is no different and no more supportable than Gobineau's founding version. The major addition is a change in methodology and sophistication—from measuring bodies to measuring the content of heads in intelligence testing. But the IQ version relies upon assumptions (the four statements above) that are as unsupportable as the old hierarchies of skull sizes proposed by nineteenth-century participants. In this light, we can gain great insight by revisiting the philosophy and intent of the man who invented this style of mental testing during the first decade of our century—the French psychologist Alfred Binet (who later became the eponym of the test when Stanford University professor Lewis M. Terman imported the apparatus to America, developed a local version, and called it the Stanford-Binet IQ test).

I shall show that Binet's intentions entirely contradicted the hereditarian version, for he believed strongly in educational remediation and explicitly rejected any hereditarian reading of his results. Ironically, the hereditarian theory of IQ (the imposition of Binet's apparatus upon Gobineau's argument) arose in America, land of liberty and justice for all (but during our most jingoistic years around World War I). The exposure of Binet's original intent does not prove him right or the hereditarians wrong (after all, a doctrine of original intent works even less well in science than in constitutional law!). Rather, Binet is right because his arguments continue to have validity, and the distortion of his wise and humane effort must rank as one of the great tragedies of twentieth-century science.

In 1904, Binet was commissioned by the Minister of Public Education in France to devise a way of identifying children in primary school whose difficulties in normal classrooms suggested some need for special education. (In French public schools, classes tended to be quite large and curricula inflexible; teachers had little time to devote to individual students with particular needs.) Binet decided on a purely practical approach. He devised a test based upon a hodgepodge of diverse tasks related to everyday problems of life (counting coins, for example) and supposedly involving basic processes of reasoning (logic, ordering, correction), rather than explicitly learned skills such as read-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ing. By mixing together enough tests of different attributes, Binet hoped that he might abstract a child's general potential with a single score. Binet emphasized the rough and ready, empirical nature of his test with a dictum: "It matters very little what the tests are, so long as they are numerous."

Binet explicitly denied that his test—later called an intelligent quotient, or IQ, when the German psychologist W. Stern scored the results by dividing "mental age" (as ascertained on the test) by chronological age—could be measuring an internal biological property worthy of the name "general intelligence." First of all, Binet believed that the complex and multifarious property called intelligence could not, in principle, be captured by a single number capable of ranking children in a linear hierarchy. He wrote in 1905:

> The scale, properly speaking, does not permit the measure of the intelligence because intellectual qualities are not superposable, and therefore cannot be measured as linear surfaces are measured.

Moreover, Binet feared that if teachers read the IQ number as an inflexible, inborn quantity, rather than (as he intended) a guide for identifying students in need of help, they would use the scores as a cynical excuse for expunging, rather than aiding, troublesome students. Binet wrote of such teachers: "They seem to reason in the following way: 'Here is an excellent opportunity for getting rid of all the children who trouble us,' and without the true critical spirit, they designate all who are unruly, or disinterested in the school." Binet also feared the powerful bias that has since been labeled "self-fulfilling prophecy" or the Pygmalion effect: if teachers are told that a student is inherently uneducable based on misinterpretation of low IQ scores, they will cease trying and will treat the student as unable, thereby producing the result by ill nurture, rather than inherent nature. Invoking the case then racking France, Binet wrote:

> It is really too easy to discover signs of backwardness in an individual when one is forewarned. This would be to operate as the graphologists did who, when Dreyfus was believed to be guilty, discovered in his handwriting signs of a traitor or a spy.

Binet felt that his test could best be used to identify mild forms of retardation or learning disability. Yet even for such specific and serious difficulties, Binet firmly rejected the idea that his test could identify causes of educational problems, particularly their potential basis in biological inheritance. He only wished to identify children with special needs, so that help could be provided:

> Our purpose is to be able to measure the intellectual capacity of a child who is brought to us in order to know whether he is normal or retarded. . . . We shall neglect his etiology, and we shall make no attempt to distinguish between acquired and congenital [retardation]. . . . We do not attempt to establish or prepare a prognosis, and we leave unanswered the question of whether this retardation is curable, or even improvable. We shall limit ourselves to ascertaining the truth in regard to his present mental state.

Binet eschewed any claim about inborn biological limits because he knew that such an interpretation (which the test scores didn't warrant in any case) would perversely destroy their aim of helping children with educational problems. Binet upbraided teachers who used an assessment of irremediable stupidity to avoid the special effort that difficult students require:

> They have neither sympathy nor respect for them, and their intemperate language leads them to say such things in their presence as "This is a child who will never amount to anything . . . he is not intelligent at all." How often have I heard these imprudent words.

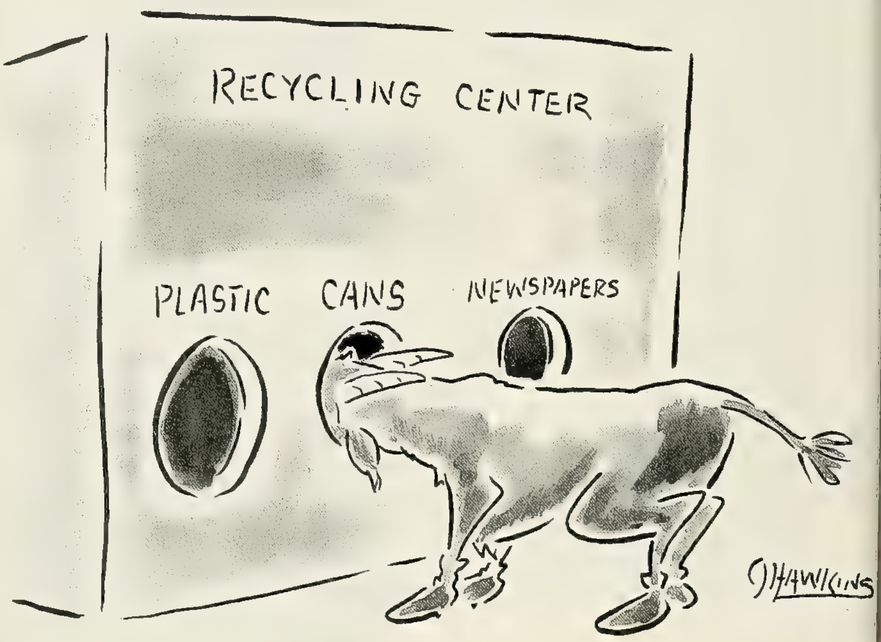
In an eloquent passage, Binet then vented his anger against teachers who claim that a student can "never" succeed as a result of inferior biology:

> Never! What a momentous word. Some recent thinkers seem to have given their moral support to these deplorable verdicts by affirming that an individual's intelligence is a fixed quantity, a quantity that cannot be increased. We must protest and react against this brutal pessimism; we must try to demonstrate that it is founded upon nothing.

Finally, Binet took pleasure in the successes of teachers who did use his tests to identify students and provide needed help. He defended remedial programs and insisted that gains so recorded must be read as genuine increases in intelligence:

> It is in this practical sense, the only one accessible to us, that we say that the intelligence of these children has been increased. We have increased what constitutes the intelligence of a pupil: the capacity to learn and to assimilate instruction.

How tragic and how ironic. If IQ tests had been consistently used as Binet intended, their results would have been entirely beneficent (in this sense, as I stated, I do not oppose mental testing on principle, only certain versions and philosophies). But the very innatist and antimeliorist spin that Binet had foreseen and decried did become the dominant interpretation, and Binet's intentions were overturned and inverted. And this reversal—the establishment of the hereditarian theory of IQ—occurred in America, not in elitist Europe. The major importers of Binet's method to our shores promoted the biodeterminist version that Binet had op-



posed—and the results continue to ring falsely in our time as *The Bell Curve*.

Consider the two leading initial promoters of Binet's scale in America. Psychologist H. H. Goddard, who translated Binet's articles into English and agitated for the general use of his test, adopted both the hard-line hereditarian view and the argument for intelligence as a single entity:

> Stated in its boldest form, our thesis is that the chief determiner of human conduct is a unitary mental process which we call intelligence: that this process is conditioned by a nervous mechanism which is inborn: that the degree of efficiency to be attained by that nervous mechanism and the consequent grade of intellectual or mental level for each individual is determined by the kind of chromosomes that come together with the union of the germ cells: that it is but little affected by any later influences except such serious accidents as may destroy part of the mechanism.

Lewis M. Terman, who codified the scale for America as the Stanford-Binet test, held the same opinion, first on intelligence as a unitary quantity: "Is intellectual ability a bank account, on which we can draw for any desired purpose, or is it rather a bundle of separate drafts, each drawn for a specific purpose and inconvertible?" Terman opted for the general bank account. He then stated his hereditarian conviction: "The study has strengthened my impression of the relatively greater importance of endowment over training as a determinant of an individual's intellectual rank among his fellows."

But Binet supplied all the right arguments in opposition—and his words, even today, can serve as a primer for the scientifically accurate and ethically principled refutation of Herrnstein and Murray's *Bell Curve*, the living legacy of America's distinctive contribution to mental testing: the hereditarian interpretation. Intelligence, Binet told us, cannot be abstracted as a single number. IQ is a helpful device for identifying children in need of aid, not a dictate of inevitable biology. Such aid can be effective, for the human mind is, above all, flexible. We are not all equal in endowment, and we do not enter the world as blank slates, but most deficiencies can be mediated to a considerable degree, and the palling effect of biological determinism defines its greatest tragedy—for if we give up (because we accept the doctrine of immutable, inborn limits), but could have helped, then we have committed the most grievous error of chaining the human spirit.

Why must we follow the false, dichotomous model of pitting a supposedly fixed and inborn biology against the flexibility of training—or nature versus nurture in the mellifluous pairing of words that so fixes this false opposition in the public mind? Biology is not inevitable destiny; education is not an assault upon biological limits. Rather, our extensive capacity for educational improvement records a genetic uniqueness vouchsafed only to humans among animals.

I was both heartened and distressed by a recent report in *Newsweek* (October 24, 1994) on a Bronx high school committed to high expectations for disadvantaged students. *Newsweek* reported:

> These 300 black and Latino students provide the basis for a strong retort to "The Bell Curve." Richard Herrnstein and Charles Murray argue that IQ is largely genetic and that low IQ means scant success in society. Therefore, they contend, neither effective schools nor a healthier environment can do much to alter a person's destiny. Yet, at Hostos, reading scores nearly doubled over two years. The dropout rate is low, and attendance is high. About 70 percent of the class of 1989 graduated on time, double the city's average.

Wonderful news, and a fine boost to Binet's original intentions. But I must object to the headline for this report: "In Defiance of Darwin," and to the initial statement: "Today, at 149th Street and the Grand Concourse, a public high school for at-risk children defies Darwin on a daily basis."

Why is Darwin the enemy and impediment? Perhaps *Newsweek* only intended the metaphorical meaning of Darwinism (also a serious misconception) as struggle in a tough world, with most combatants weeded out. But I think that the *Newsweek* editors used "Darwin" as a stand-in for a blinkered view of "biology"—in telling us that this school refutes the idea of fixed genetic limits. Biology is not the enemy of human flexibility, but the source and potentiator (while genetic determinism is a false theory of biology). And Darwinism is not a statement about fixed differences, but the central theory for a discipline—evolutionary biology—that has discovered the sources of human unity in minimal genetic distances among our races and in the geological yesterday of our common origin.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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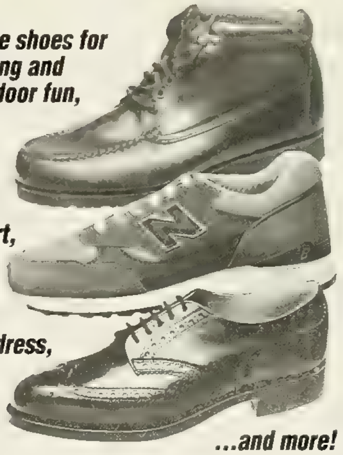

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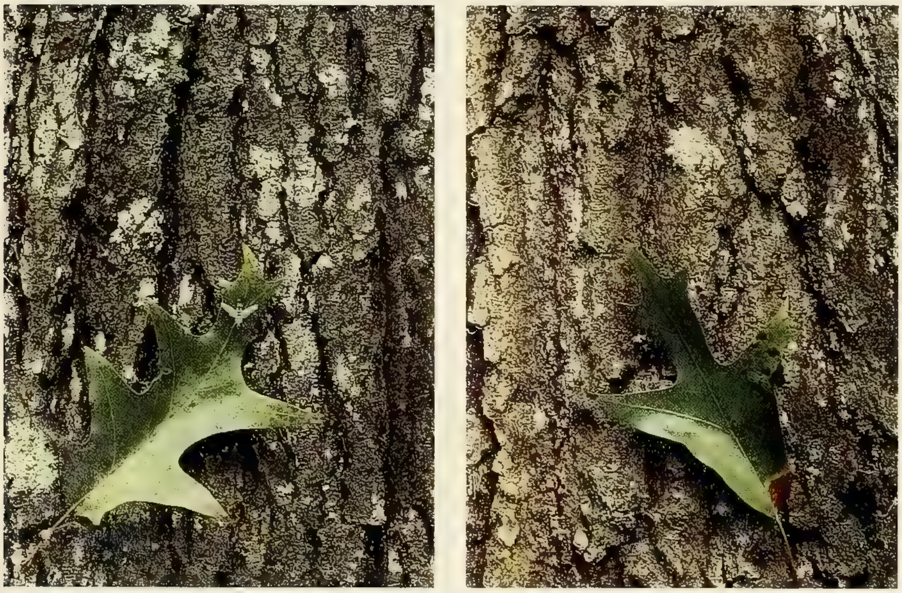
Pellucid Bayou, Mississippi

by Robert H. Mohlenbrock

During the Ice Age, which lasted from about 1.6 million to 10,000 years ago, glaciers periodically scoured the northern portions of the North American continent, grinding rock into tiny particles. This dust was picked up by the wind and deposited in the Mississippi floodplain as a fine-grained soil known as loess. The thickest layers accumulated on the eastern side of the Mississippi and Missouri Rivers, where the prevailing westerly winds encountered bluffs. Near Natchez, Mississippi, loess deposits are as much as thirty feet deep, although eroded in places because of continuous wind action.

About twenty-five miles east of Natchez, in Homochitto National Forest, deposits of loess form gentle ridges adjacent to Sandy Creek and its tributaries, such as Pellucid Bayou. The original deposits are shallower than at Natchez—about fifteen to twenty feet thick—but because the wind is less intense, they are less eroded. Plants that grow in the river bottom can also be found on these nearby ridges, alongside upland species, providing a much diversified habitat.

I wandered onto the loess ridges during a pleasant mid-April day. Basswoods and tulip poplars were common upland trees, along with American beech, southern magnolias, occasional upland species of oaks, and the evergreen American holly. In addition there were occasional trees that usually grow in bottomland forests along the Mississippi River. One of these was Nuttall's oak, a pin oak look-alike with larger acorns that is found only in the forests adjacent to the Mississippi River from New Orleans to southern Illinois. Even more interesting to me was that on the ridges above Sandy Creek and Pellucid Bayou, I saw cherrybark oaks growing next to southern red oaks. This was not only an example of a bottomland species growing next to an upland one; to me it was also evidence that these two trees, which many botanists consider the same species, are really distinct.



Differences in the leaves and bark of cherrybark and southern red oak, left and right, suggest they are distinct species. Opposite page: The waters of Pellucid Bayou flow through a fine-grained soil known as loess.

Photographs by Stephen Kirkpatrick

I live in an area in southern Illinois where both cherrybark oak and southern red oak occur, but they are never found together. The cherrybark oak grows in wet, bottomland forests, while southern red oak grows in the dry woods found on ridges. A trained eye can easily tell these two kinds of trees apart. The bark of a mature cherrybark oak, with its smooth patches, resembles the bark of a cherry tree (as the name implies), while the more broken-up bark of the southern red oak is characteristically oaklike. Cherrybark oak has leaves with five or seven lobes, the terminal one not decidedly curved; southern red oak has leaves with three or five lobes, with the terminal lobe strongly curved. In addition, the base of a cherrybark oak leaf runs nearly straight across, while the base of the southern red oak leaf is very rounded and resembles an inverted bell.

The problem is that in classifying plants, botanists prefer to rely on reproductive structures, such as the flowers and the fruits. These parts tend to vary less from individual to individual than do nonreproductive structures, such as leaves. For example, anyone who has ever examined the leaves of a northern red oak knows that no two leaves are exactly alike. However, the acorns of one northern red oak are identical to the acorns of any other northern red oak.

Most of my colleagues consider the cherrybark oak to be a habitat-induced variant of the southern red oak. The acorns of the two trees are very similar, with only a few, seemingly minor differences. The differences between the leaves and bark, they believe, result somehow from differences in the habitats where the trees grow. I have always been skeptical of this, regarding the trees as two distinct species.

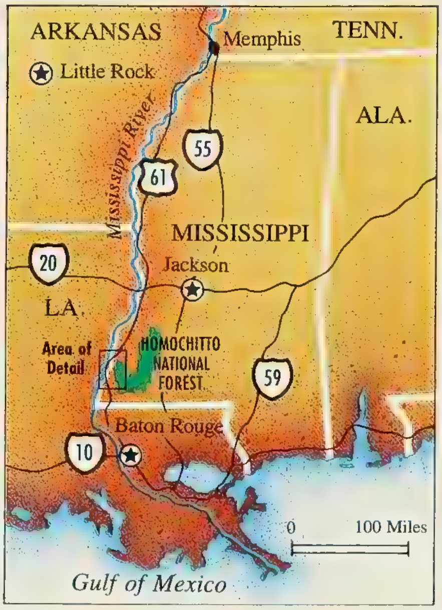
The thick-petaled swamp leather flower blooms in early summer.

As I walked along the ridge above Sandy Creek, I came upon a large cherrybark oak growing right next to an equally large southern red oak. The leaf and bark differences between the two couldn't have been more striking, yet the soil they were growing in and their exposure to the sun was essentially identical. This did not prove that they were distinct species, but I felt my view was borne out.

Moving downslope from the ridgetop, I observed umbrella magnolia, an Appalachian species with two-foot-long leaves, growing with American elm, sweet gum, and hop hornbeam. As I walked farther down into a ravine (locally called a hollow) between adjacent ridges, I found myself in lush vegetation. Clumps of Christmas ferns covered the slopes, interspersed with maidenhair fern (rare this far south) and a plant I had never seen before, fetid trillium, an evil-smelling plant with three rusty-maroon petals.

Other plants in the hollow included a white-flowered violet and a blue-flowered violet; climbing hydrangea and bittersweet (both are vines); and doll's-eyes, a member of the buttercup family whose black-dotted, round, glossy white fruits resemble the eyes of a porcelain doll. Continuing downslope I observed two very uncommon plants, a beautiful flowering shrub known as the silky camellia and a vine related to the magnolia family called star vine because of its half-inch-wide, star-shaped, strawberry-pink flowers. Finally I came to Pellucid Bayou, beneath whose clear water I could see the sandy-colored loess of the stream bottom.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.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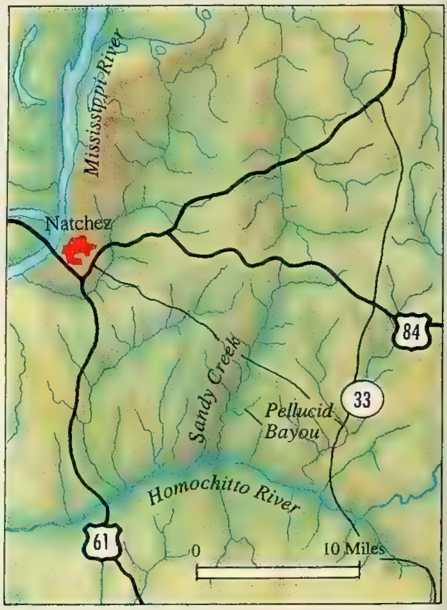
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TECHNOLOGY UPDATE

New device turns any electrical outlet into a phone jack

Engineering breakthrough gives you unlimited phone extensions without wires or expensive installation fees

By Charles Anton

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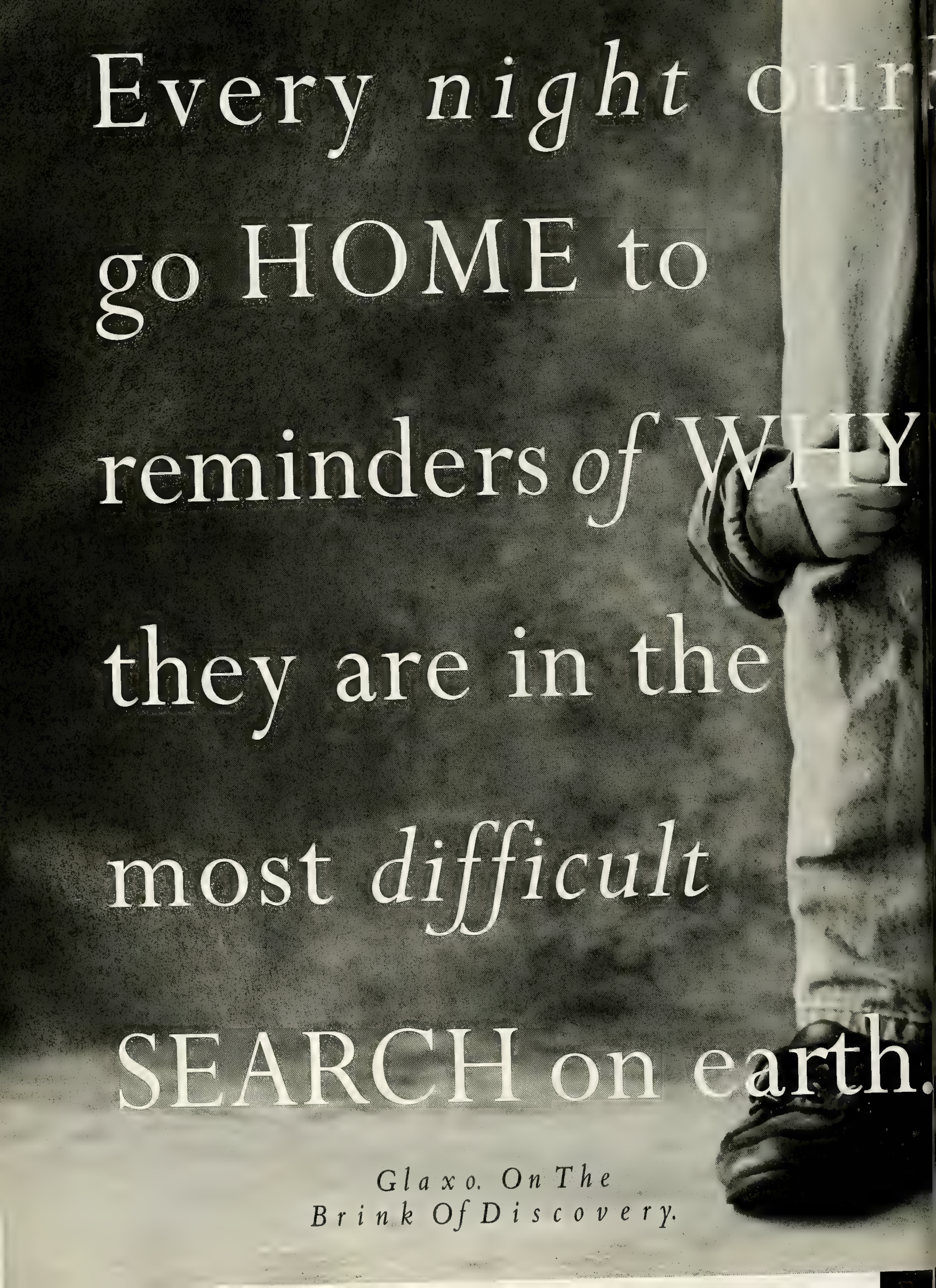
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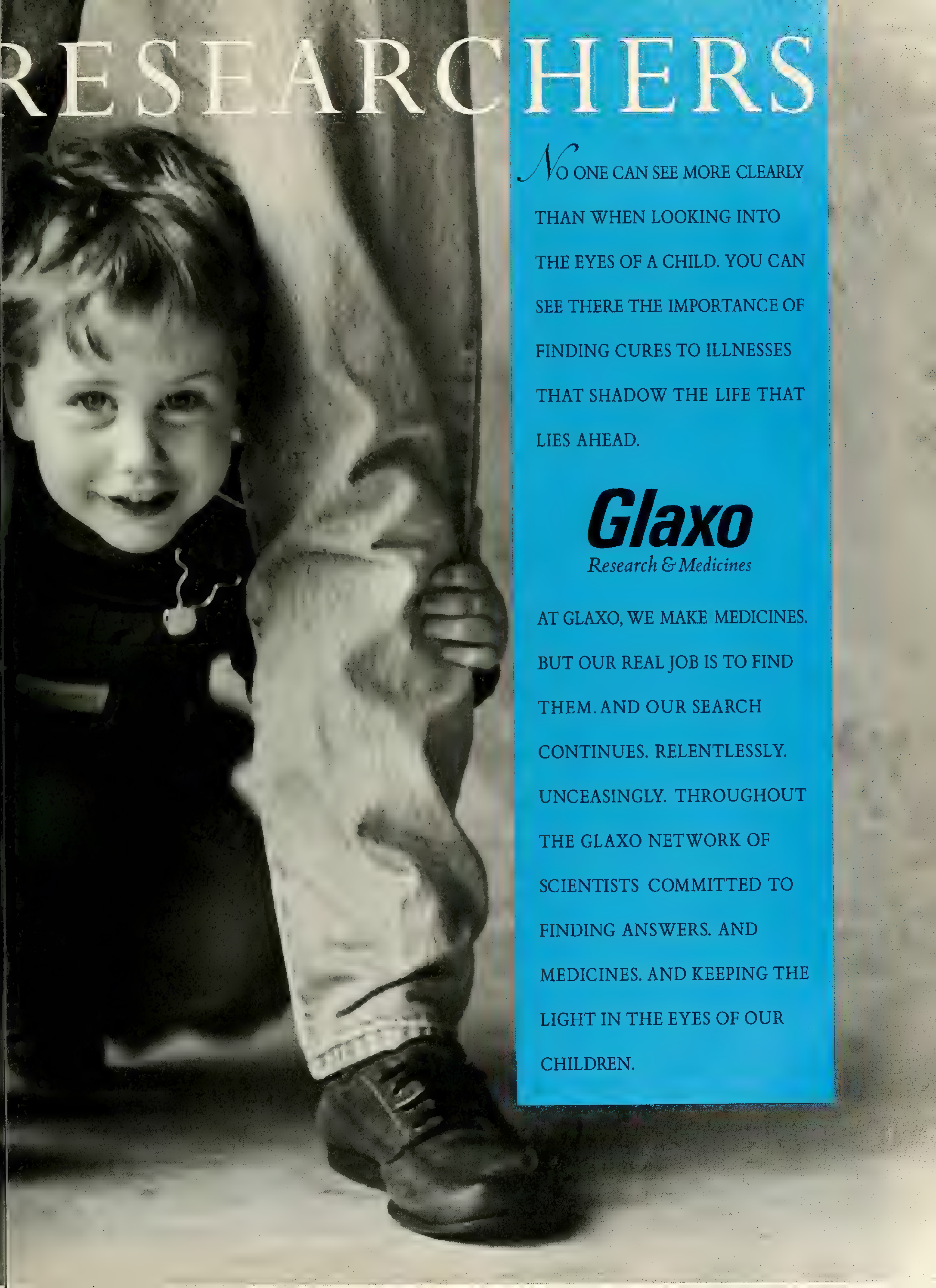

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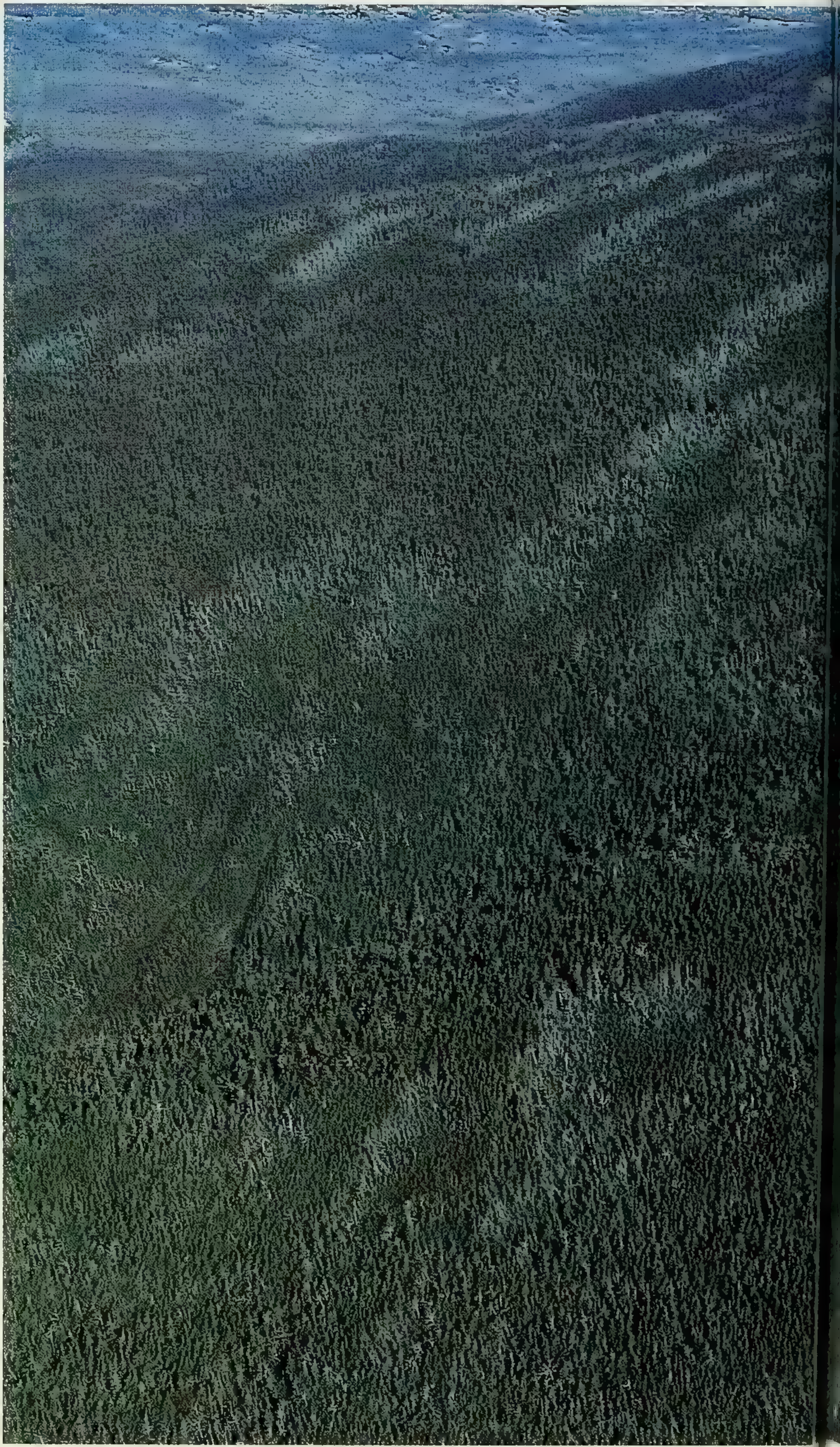
Waves in the Forest

High up in the mountains of Japan and North America, the cycle of death and renewal takes on a striking pattern

Peter J. Marchand

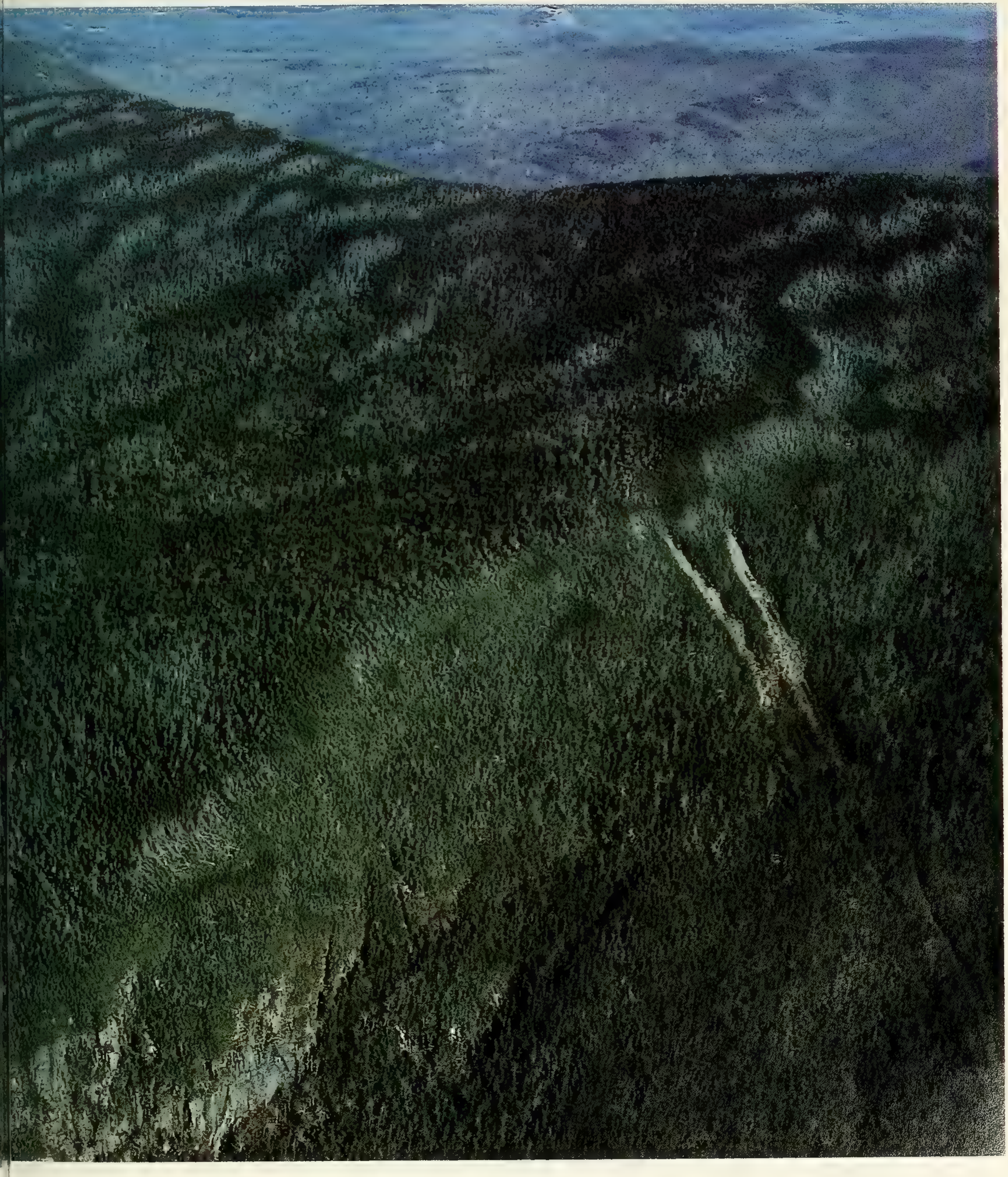


The Japanese call it, unpretentiously, "the mountain with dead tree strips." The name is fitting, for the upper slopes of Mount Shimagare are punctuated by crescent-shaped bands of bare, silver tree trunks standing starkly against a backdrop of dark evergreen foliage. The bands are moving lines of destruction, sweeping through the subalpine forests with an unstoppable force, claiming every mature tree in their path. The sight is a common one in the Yatsugatake and Chichibu Mountains of central Japan, but it has nothing to do with the industrial pollution that seems to have plagued the forests of central Europe and elsewhere. For as long as anyone can remember, the bare strips have been there, one following another like a pounding surf. Curiously, whatever was devastating the aging stands never harmed saplings and thus never took the whole forest.

The only other place in the world where this phenomenon is known is the northeastern corner of North America. Here "the mountain with dead tree strips" might be Whiteface in the Adirondacks of upstate New York, Lafayette in New Hampshire's Franconia Range, Katahdin in the wild interior of Maine, or any of a number of northern Appalachian peaks stretching all the way to the Gaspé Peninsula in Canada. The pattern everywhere is the same: crescent-shaped bands of dead and dying trees appear to advance through the forest, leaving vigorous saplings in their wake. Behind this dieback front, the age and height of these survivors gradually increase until the regenerating stand "crests" at the next line of dead trees. Speeded up by time-lapse photography, the dying and regenerating forest would appear to be moving in waves. Each crest is separated by perhaps 300 feet and, in real time, takes 35 to 100 years to arrive at any given point. This is the shortest cycle of natural forest succession of which I am aware, occurring both here and in Japan only in high-elevation fir forests.

"Fir waves," as we now label them, were first reported in the modern scientific literature in the late 1950s by Y. Oshima, *The slopes of North Twin Mountain, in New Hampshire's White Mountains, are streaked with crescent-shaped zones in which nearly every fir tree more than thirty-five years old is dead or dying.*

Alan Briere



H. Iwaki, and their Japanese colleagues; in the mid-1970s, Douglas Sprugel (then a graduate student at Yale's School of Forestry and Environmental Studies) described the phenomenon in this country. At the time, none of these researchers understood why the trees died as they did. Surprisingly, these early accounts failed to stir up much excitement within the scientific community, and little information filtered down to the familiar level of natural history. Fir waves continued to escape recognition by hikers who often passed right through dieback zones in the high balsam forests of the northern Appalachians. Most dismissed the phenomenon as blowdown, although even cursory examination would reveal that the trees die standing and blow over only years after their death.

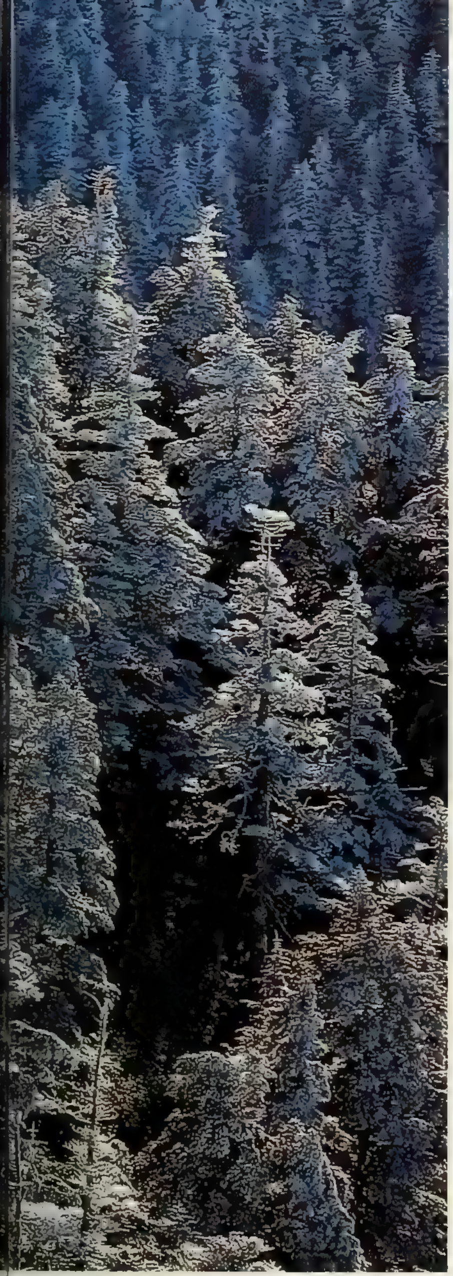
My interest in fir waves, particularly in the mechanism of tree death and the persistence of this phenomenon over time, stemmed largely from my years of studying timberline and the limits to tree growth in the northern Appalachian Mountains. The subalpine balsam fir in the dieback zones—growing at lower elevations and in seemingly milder conditions than the trees I was used to studying—often looked far more abused than any of my timberline subjects.

I became serious about fir waves while visiting the laboratory of Richard Waring at Oregon State University. As I browsed through some Forest Service photo files, I happened upon something quite unexpected. On aerial photographs of subalpine mountain hemlock forests in the Oregon Cascades, I saw circular patterns of gray that vaguely resembled the crescent-shaped dieback fronts of a fir wave. A subsequent search through the scientific literature, combined with field investigation, revealed that these were localized pockets of *Phellinus* infection, a virulent fungal pathogen that was killing mature mountain hemlock trees. My attention was immediately attracted by certain similarities between what was happening in the forests of Oregon and what was documented in Japan and the Appalachians. Dieback of the mountain hemlock seemed to be spreading outward in ever expanding circles, with vigorous regeneration occurring behind the front. Here, I thought, we might have a model for wave mortality in fir forests, in this case with a known cause.

A collaborative research proposal with Waring was not long in the writing. Our initial working hypothesis was fairly straightforward. We surmised that as the mountain hemlock stands matured, the long-term sequestering of nutrients in the woody tissues of the tree eventually depleted the soil. The aging trees then were no longer able to garner sufficient resources, primarily nitrogen, to produce the chemical compounds that would ward off invaders such as the *Phellinus* fungus. Hence, the small organism prevailed, the stressed giant fell, and *Phellinus* moved onward and outward from the focus of its infection, in widening circles, to claim one new victim after another in the old stand.

Meanwhile, we hypothesized, decay of the dead trees released nutrients back to the soil and new saplings grew vigorously in the center of the circle, able to defend themselves now from pathogens of all sorts, including the persistent *Phellinus*. A couple of centuries later, soil nutrients waning, the saprophagous fungus found weakness again, turned parasitic, and started the process anew. Like ripples in a pond, the successive rings of dieback radiated outward into the maturing forest—and all I had to do, it seemed, was explain why they formed crescents, instead of circles, in the mountains of the Northeast.

So home I went, armed with new ideas and methods for studying the metabolic



Kazuma Anezaki; Nature Production

Fir trees on a mountain in Japan, left, are covered with rime ice, one of several natural factors that sometimes combine to kill the mature trees in the dieback zone of a fir wave. Rime ice, below, develops when atmospheric moisture freezes on contact. It takes a heavy toll of fir needles exposed to strong winds.

Peter J. Marchand

efficiency and disease resistance of my ailing trees. While Dick Waring, and his colleagues Kermit Cromack and Pamela Matson, worked out the details of the hemlock stress cycle, I sought additional expertise from William Reiners, Ingrid Burke, and Jeff Foster, then at Dartmouth College. With their help, and with a small cadre of my own students, I confidently initiated groundwork in the White Mountains of New Hampshire.

Our working hypothesis hit two snags right away. Bill Reiners showed that the deep litter of the cold forest floor in the Northeast yielded plenty of mineralizable nitrogen (hence, there was no shortage of nutrients), and a consulting forest pathologist gave our trees a clean bill of health (no root pathogens). Furthermore, I was unable to turn up any convincing measure of declining photosynthetic efficiency in the dying fir trees.

I did, however, glean two important bits of information from analyses of leaf surface area and wood production (a measure of tree vigor) for individual trees in the ailing stands. One was statistical confirmation of what our eyes were telling us: trees in the dieback zone had fewer green needles than did healthy trees ahead of the approaching wave. The second piece of information was that there was a high incidence of incomplete growth rings in the outer wood of trees in the dieback zone (representing the most recent years of the trees' life). This reduction of growth had nothing to do with differences in the ages of the trees; that is, trees from relatively young stands (thirty-five years old) were apparently experiencing the same problems as trees from much older sites. So I reordered my questions: (1) If the needles of dieback zone trees were still photosynthesizing efficiently, but there were fewer of them, what was going wrong? and (2) Why were trees in the dieback zone showing symptoms of incomplete or missing growth rings several years before succumbing to the advancing wave?

The answer to the first question came relatively quickly. One crisp New England winter day I decided, as much for sport as anything, to climb Mount Moosilauke in New Hampshire and have a look at one of my study sites. What I found when I got there was snowpack littered with ice-encrusted foliage—not just a lot of individual needles groomed from the canopy by winter winds, but whole branch tips, green and healthy, broken off and lying on the snow. My first thought was that cold-frantic red squirrels were zealously harvesting the abundant cones from the trees, but a more reasoned inspection soon revealed the true culprit: rime ice. Rime ice develops as supercooled cloud droplets sweep across the cold mountain forests and freeze upon contact and is a common occurrence in this part of the world, as well as in Japan. On Mount Moosilauke, rime ice was accumulating in the upper crown of the trees and was apparently taking its toll of fresh needles in the exposed dieback zone of the fir wave, where the wind was unabated and trees lacked the protection of a closed canopy upwind.

Anxious to quantify just how much foliage might be lost in the course of a winter, and not wanting to wait another year, Ingrid Burke and I returned to the site a week later armed with snow shovels and litter screens. By digging several six-foot-deep pits down to the bottom of the snowpack and sliding our screens under the undisturbed snow, we hoped to catch during spring thaw a sizable sample of the green needles that had accumulated in the snow that winter. Six months later we had some preliminary estimates: a startling 20 percent of the exposed canopy, generally branch tips with the youngest and most productive needles, had been lost to the rime ice. This represented a significant loss of the carbohydrates that had been stored through the winter in the conifer foliage, energy reserves that would keep the tree alive and help support the flush of new needles that would soon follow. Furthermore, it represented a reduction in photosynthetic potential, both in the spring before new needles are functional

Trees rocked by wind may suffer root damage, especially where soils are shallow and rocky. The damage opens the trees up to pathogens. In time, the trees may die and topple over. Eventually, the dieback zone of a fir wave is littered with leaning and fallen trees, left and below.
Photographs by Alan Briere

and during subsequent growing seasons.

Comparable losses were confirmed the following year by Jeff Foster in a more extensive investigation at our Mount Moosilauke study site. These findings could easily explain a reduction in wood production the following summer or failure altogether during marginal years to add complete annual rings. The amount of wood produced for a given leaf surface didn't necessarily change, but less foliage meant less energy to satisfy the various needs of the tree—for example, production of new roots or leaf buds—and wood is a low priority relative to the tree's other requirements.

Still, one thing bothered me. Failure to produce wood doesn't kill trees. In itself it isn't of any particular consequence—trees in the arid Southwest often show dozens of missing rings in their lifetime—but it is symptomatic of stress, and I wondered if there was more to it than a reduction in foliage. Were scant energy reserves being siphoned off for some more pressing need?

The next revelation came during a midsummer night windstorm when I was camped within a fir wave at one of my study sites. Trees swayed violently around me all night, and on more than one occasion, I was awakened by thudding noises that seemed to be coming from beneath me. The next morning I emerged from my tent to find, not far away, a sizable fir tree leaning into its neighbors, its roots torn up on one side. It dawned on me that what awakened me in the night could have been tree roots straining against the very angular rock of the subalpine soil and breaking right under me. I immediately began excavating roots of upright trees, carefully tracing their tortuous paths through the ancient felsenmeer (frost-shattered rock) that held them. I found broken roots in abundance, some fresh from the night's violence, others from past storms.

So once again, with the help of Ingrid Burke and my student assistant, France Goulet, I undertook to quantify something hidden beneath my feet. And my analyses told yet another story. Trees in the dieback zone of the fir wave, which bore the full brunt of the wind, suffered significantly greater root damage than did trees in the mature stand only a short distance ahead of the wave front. But that wasn't all. The xylem, or woody vascular tissue, of the damaged roots was noticeably discolored, as if by an invading pathogen. I quickly called in another pathologist, this time Tom Harrington, a root specialist from the University of New Hampshire, and in little time he isolated and identified the fungus *Resinicium bicolor* in our trees.

Resinicium is not a "big-tree killer" like the fungus *Phellinus,* which can enter one root and bring down the whole tree, as in the mountain hemlock stands of Oregon. *Resinicium* is a relatively unaggressive species, subsisting for the most part as a saprophytic organism attacking dead organic material on the forest floor. In many of our front-line trees, however, it was widely distributed throughout the root systems, turning parasitic and apparently entering through many points of injury. And the host tree was doing itself in by its response to the invader.

Fir reacts to fungal infection by producing what is termed "wetwood"—water-soaked, nonfunctional xylem. Bacteria often proliferate in wetwood, removing most of the oxygen and rendering the tissue unsuitable for the fungus, but the trade-off is that a portion of the root is taken out of service. This may be a small problem for a tree with sufficient carbohydrate reserves to replace the injured roots (root turnover is an ongoing process in trees). But a tree with many infected roots and low reserves, perhaps due to heavy foliage losses, may not be able to keep up with the sloughing of roots, let alone produce new bole, or trunk, wood.

How might this process of mechanical injury, root infection, and host response translate into waves of dead trees? *Resinicium* is apparently abundant in soils throughout the fir forests of the northern Appalachians, but there is no evidence to suggest that it becomes concentrated at any one location, as does *Phellinus* in the infected stands of mountain hemlock in the West. What does appear to be concentrated in these narrow, wind-exposed bands, is stress, and this gives rise to the accelerated entry of *Resinicium* into the root systems. And here is where all the pieces begin to fit.

Forest stands in wave-prone areas are essentially even-aged. The trees all start together when the canopy opens up owing to some disturbance, and fir, favored by its frequent and abundant seed crops, fills the gap quickly. Initially, growing conditions are relatively good. The young trees are reasonably sheltered and have ample moisture, and as light floods the forest floor they grow vigorously. With the number of trees sometimes exceeding 5,000 per acre, however, the competition for scarce resources soon becomes intense. The trees crowd each other, lower branches get shaded out, and with time, the amount of foliage relative to the increasing mass of the tree diminishes.

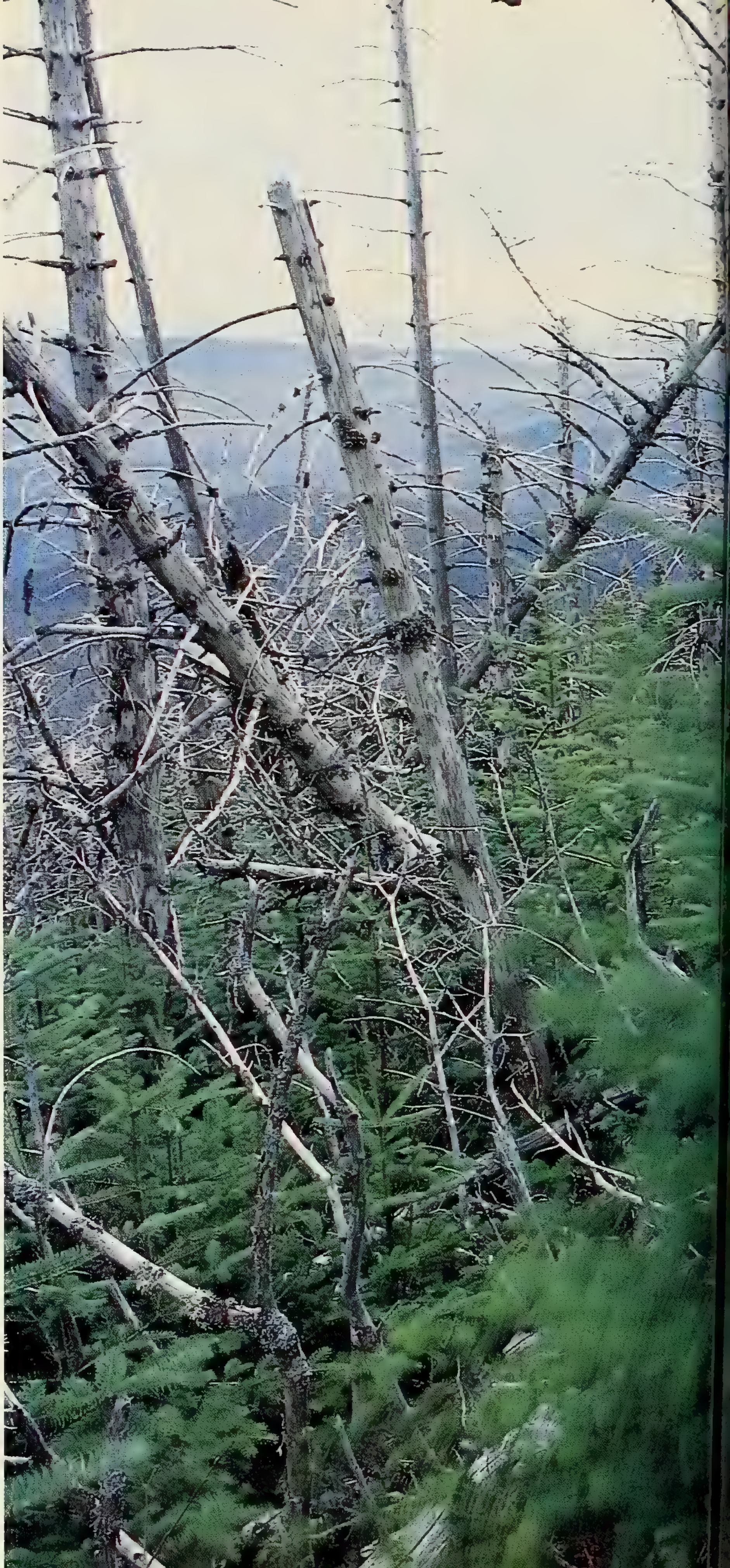
When the trees are young and vigorous, they often have enough surplus energy to deal with problems of mechanical injury, such as tissue repair and replacement. As the trees grow larger and have more living tissue in roots, trunk, and crown to provide for, their total energy requirements become greater. Eventually, trees reach a point where they can produce only enough

Saplings within a fir wave are unharmed and even benefit as more sunlight reaches the forest floor and as decaying trees release nutrients locked up in their wood for decades.
Alan Briere

from photosynthesis to maintain themselves. Once they are tall enough to suffer greater pressure from the wind and from heavy accumulations of rime ice, the weather-beaten trees begin to lose foliage and soon are barely breaking even in terms of meeting their maintenance needs.

If a single tree goes down now and opens up a small gap in the canopy, the force of the wind at the exposed canopy edge increases. During winter, the trees situated along the downwind side of the gap lose still more foliage. In the summer, released from the stabilizing grip of the deep snowpack, the trees lean in the wind, straining back and forth against the fractured bedrock beneath a shallow soil, and their root systems suffer considerable abrasion. Enter the saprophytic-fungus-turned-parasite and the tree's problems are compounded, with still more demand placed on limited photosynthetic reserves. The tree responds to this injury by taking the root out of service, hence limiting its own access to soil resources. In fact, the tree often overreacts, shutting off more root tissue than was actually damaged. So now the tree is under duress at both ends. Losing foliage and roots at an accelerated pace, and in an environment where growing conditions may be marginal to begin with, the tree's loss is just too great. The tree dies, and the opening in the canopy grows larger. As this process is repeated along the exposed edge, a fir wave is born.

The details may differ in the forests of Japan, but the outcome is the same. To the individual tree, the result is, of course, disastrous. To the aging forest as a whole, however, the process has a more positive effect. Nutrients that have been tied up for decades in the wood of the trees are released, sunlight reaches the understory once more, and a host of other organisms flourish before the canopy is closed again by the dominant species. This process of cyclic renewal has probably been going on for as long as fir has occupied these mountaintops, maintaining the subalpine forests of Japan and the northern Appalachians in much the same state since shortly after the last ice age. □



A tenor pan player in Port of Spain
Matthew Benson

Trinidad Pan

The upbeat sound of the Caribbean steel band was born in the Great Depression

by Donald R. Hill

People outside of Trinidad call them steel drums, but Trinidadians call these tuned metal instruments, and the percussive sounds they produce, pan. For many Trinidadians, pan is a symbol of their Creole culture. For others, it evokes the warmth and joy of the Caribbean experience—the people, the sky, the sand, and the sea. But when I first went to live in Trinidad, I hated pan.

My complaint was not the same as that of proper middle-class Trinidadians, who, during World War II, began to resent the "brawling" young men from the slums of Port of Spain whose music and general behavior "gave fatigue" to respectable people. Mine was more selfish and practical. As an ethnomusicologist, I was interested in the old Carnival traditions, such as those that I experienced while living in nearby Carriacou, Grenada. (Like all New World Carnivals, those of Carriacou and Trinidad—and New Orleans's Mardi Gras as well—were pre-Lenten festivals influenced by both Catholicism and a great West African cultural heritage.)

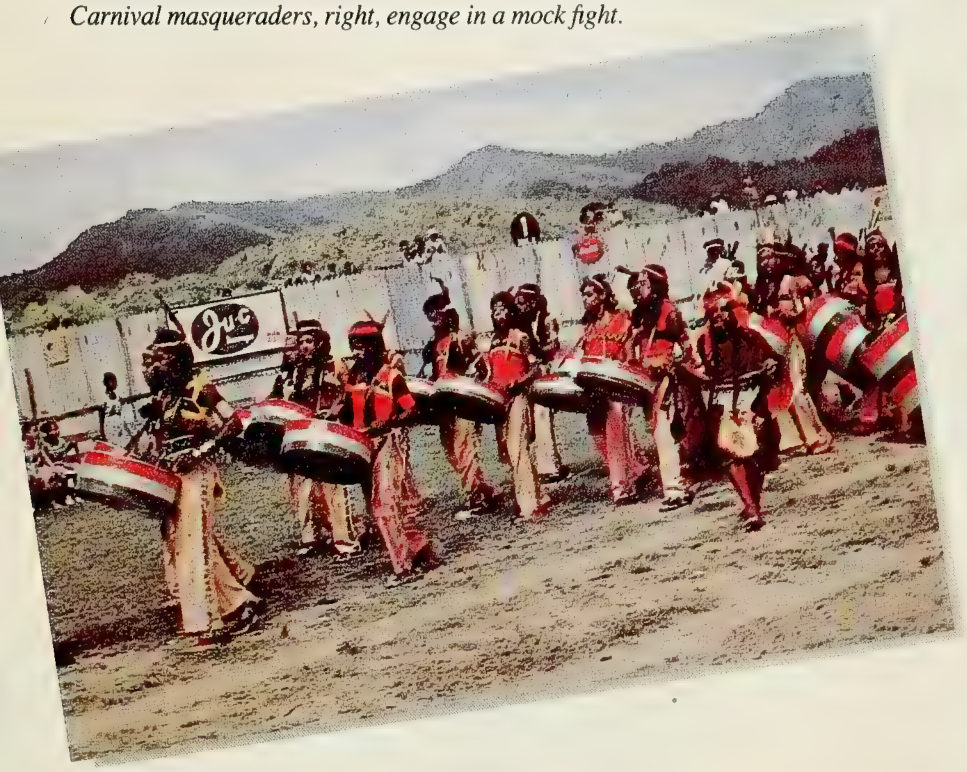
When I arrived in Trinidad after leaving Carriacou in the early 1970s, only vestiges of the old culture remained. The steel bands and the modern fancy masquerade bands had, by then, almost put an end to the older Carnival, with its smaller masquerades, strolling musicians, and traditional skits that had evolved since the beginning of British colonial rule at the turn of the nineteenth century.

These older Carnival activities could be "read" for important cultural information and history. More importantly, they could be enjoyed simply for what they were: the stilt walker (moko jumbie), who danced on stilts starting at daybreak on Carnival Monday (Jouvay); the midnight robber, who engaged rivals in bold talk—a rap full of wonderful, alliterative speech; the "pierrots" who, like the robbers, would also speak in broad braggadocio as they fought one another with whips; and the glorious string bands—said to have come from nearby Venezuela—that played their old-time calypsos, waltzes, and castillians with great savoir-faire as they strolled along, sometimes fronting a group of masqueraders.

By the early 1970s, old Carnival could be seen only in managed, televised government competitions. On the streets, Carnival-loving Trinidad rushed headlong into the era of large, fancy masquerade bands and steel orchestras that played set pieces (road marches or calypsos for Carnival revelry) over and over again.

Eventually, I admitted that this modern Carnival, having shed any relics of British colonial society, probably best represented the society of the new nation of Trinidad and Tobago, which became a commonwealth in 1962 and an independent republic in 1976, after having had a long colonial history as, first, a Spanish colony and later, a British colony. Although Carnival evolved mainly under the British, some of its earliest features were brought by Roman Catholic French planters and their slaves from neighboring islands. Carnival changed greatly after the emancipation of the slaves in 1838 and again in the 1880s, when it was dominated by "jamets," or "diamettres" (those who lived "under the line"), and the working poor from the fringe districts of Port of Spain. This heterogeneous lot consisted of former slaves, immigrants from nearby islands, and formerly indentured Africans who—together

A costumed steel band from the early 1950s, postcard below, included old-fashioned boom bass drums (at right). Traditional Carnival masqueraders, right, engage in a mock fight.



Royal Victoria Museum, 1994

with East Indians, a few Chinese, and others—had come to the island as sugar cane workers after slavery ended in 1838. Many had moved to towns, risking an uncertain future in order to escape rural poverty. Some lived in barracklike row houses; each had only one door, which led to a shared yard with a single standpipe for water. These yards became centers for social gatherings.

Ethnic groups, such as Yorubas, Congos, and Radas—all of West African origin—as well as trade groups, such as dockworkers and shop clerks, began to form their own "calinda" bands, not only for Carnival but also for other special occasions. From the late 1800s until the 1940s, approximately sixty-five calinda yards existed in two main areas of Port of Spain. Calinda is a name long associated with a Caribbean dance but may also refer to a ritualized fight, or "game," accompanied by drumming; it is much like boxing except that the combatants hit one another with staves (about two and a half feet long), not gloves.

Some of the first big names in stick fighting were One Man Biscoe and Mungo the Dentist (who was thought capable of extracting an opponent's tooth with a single, sharp blow). Lucretia, Peg Top, and Bullinder (a transvestite) were their female backers, who supported the stick fighters with songs and verbal insults aimed at their opponents. Early big name bands were the Tai-Pings, the Cocoa-bagged Devils, the Maribones (wasps), and the Freegrammers. Stick fighters' loyalty was to their yard. In the 1880s, their Carnival routines sometimes went beyond engaging their competitors in song and battle and developed into full-scale riots—or incipient revolts against the British authority.

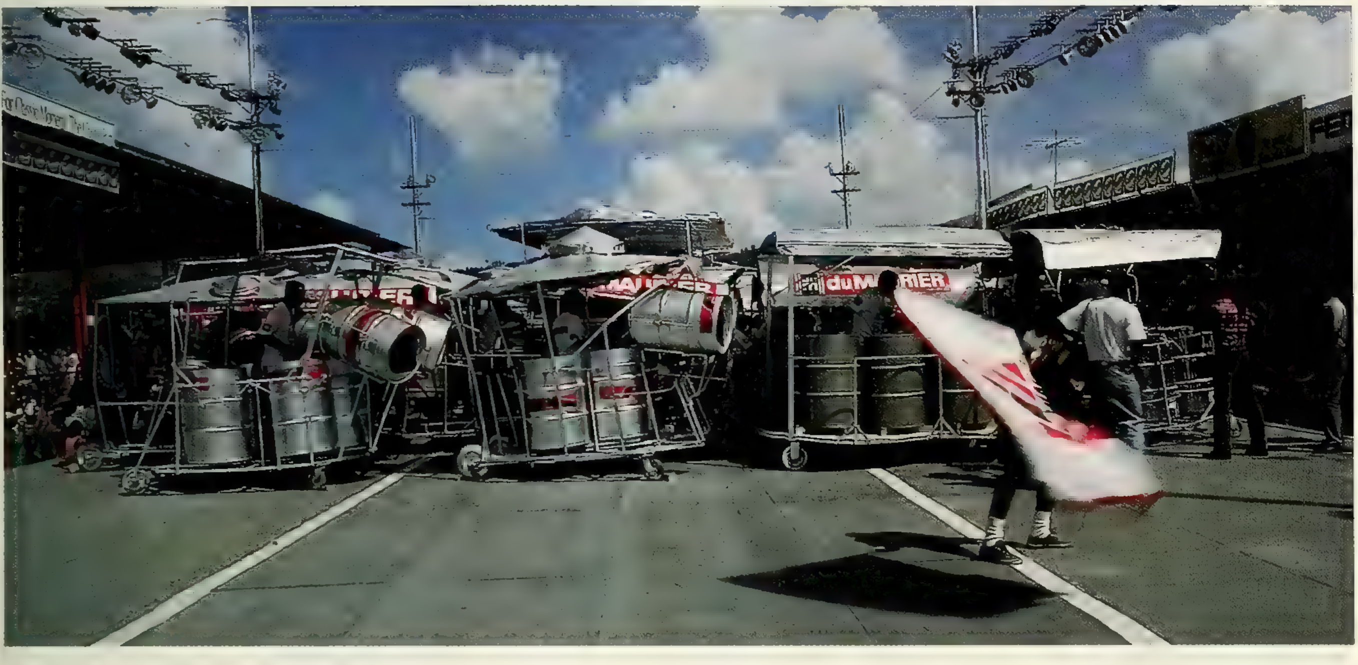
After several confrontations, the British banned the calinda bands in 1883. In some areas outside the major towns, where the new law was indifferently enforced, drums gave way to bamboo orchestras called the tamboo bamboo. Hollowed-out bamboo tubes were struck against the ground or hit with short sticks to make mellow, percussive sounds. Similar bands, apparently with West African roots, are found elsewhere in the West Indies and in Venezuela. Away from the eyes of the authorities, stick fighting continued right down to the present era. As late as 1971 in Carriacou, Grenada, I happened on an illegal stick fight on Jouvay morning. Unfor-

Courtesy U. S. Army

THIS IS THE SIGN OF VICTORY FOR THE ALLIES
V
CALYPSO SINGERS - February 1943
ir overtures...reflected and affected publi
n and Government policy!"

Pan stands are wheeled through Port of Spain's principal performing area, below. Bottom, from left to right: Trinidadian calypso singers Lord Invader, Growler, Atilla the Hun, and Roaring Lion in 1943.

Abigail Hadeed



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tunately—or maybe fortunately since it can be brutal—I had missed the combat and could only enjoy the drumming and singing as the stick fighters rested.

By the middle of the 1890s, Carnival in Trinidad changed radically, as the nascent Creole middle class—persons born in the West Indies of African, Middle Eastern, or European descent—and Asians began to take over in the larger towns of Port of Spain and San Fernando. Creoles were mainly Catholic and Afro-Trinidadian, but some were French, British, Madeiran, Syrian (a generic term for Levantine Arabs and Sephardic Jews), Chinese, or of mixed descent.

About 1894, the masquerade band of twenty to thirty costumed people began to emerge as a component of the new Carnival. Called social unions and modeled after the stick fighter bands, masquerade bands named Royal Britannia, the Iere Belles, and the White Rose Band collectively portrayed a single theme. Norman Le Blanc, of the White Rose group, for example, once dressed as a dashing courtier of the Elizabethan Age.

Calypso, a name then associated with the newly composed songs in English, gradually replaced the old Carnival songs sung in Creole. Although the British were a small minority, English was the language of government and commerce. French was spoken by most of the Creole elite, Creole or patois by ordinary people, and Hindi by East Indian laborers. Singing masqueraders, called chantwells, led each social union in parade and song as the Carnival group danced in the streets to the accompaniment of a string band. Masquerade bands seemed to delight in their Britishness, as did the chantwells in their panegyrical use of the English tongue. Chantwells, for example, might dress as Imperial South African soldiers and then sing of the British victories over the Afrikaners in the Boer War.

Carnival costumes were assembled in yards or other convenient locations, renamed "masquerade camps" for the occasion. There, the chantwells and masqueraders practiced their dancing and singing routines. A corner of the masquerade camp was sometimes covered with a tarpaulin or sail and called a calypso tent; more formalized singing competitions took place in this area. Although the older style calinda bands still performed for many decades, by the close of World War I, the modern Carnival of fancy masquer-

ades and calypsos was firmly established.

In the 1920s and early 1930s, calypso tents became independent of the fancy masquerade bands. In 1934, two of the top calypso singers, Atilla the Hun (Raymond Quevedo) and the Roaring Lion (Raphael de Leon) went on a recording trip to New York City, sponsored by Trinidadian businessmen. Although the first instrumental calypsos had been recorded as early as 1912 and Trinidadian Wilmouth Houdini's songs since 1928, Atilla and the Lion's visit popularized calypso outside Trinidad. Soon, the newest songs of the season were being recorded in New York—as well as in Trinidad.

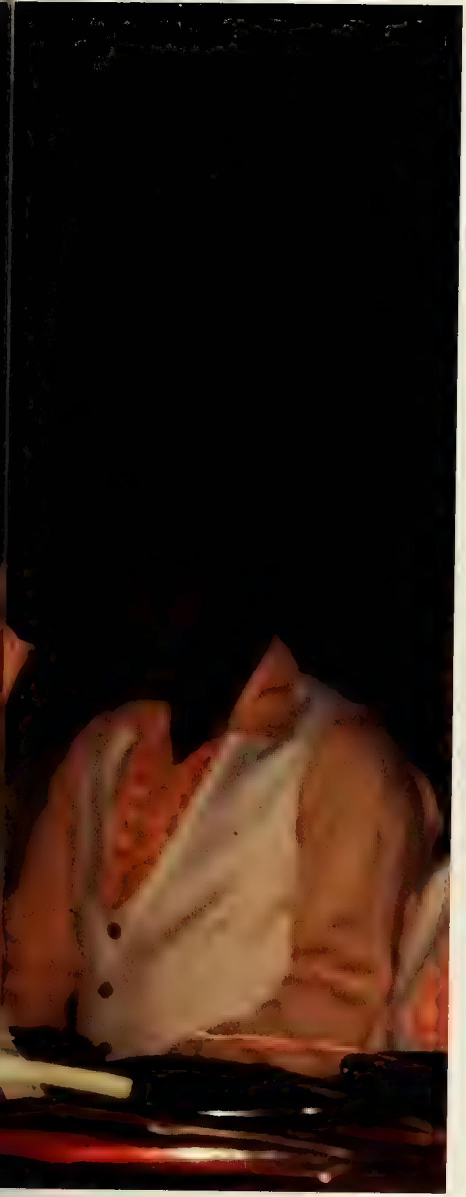
In the meantime, Trinidad was experiencing the Great Depression, reflected in the lyrics of a calypso song by the Growling Tiger (Neville Marcano):

> Anywhere you go you must meet
> people sad
> They search for employment, none can
> be had
> They start to drop down dead in the
> street
> Nothing to eat and nowhere to sleep
> Our kindhearted employers, I appeal
> now to you
> Give us some work to do.

Conditions were not much better for those who could find jobs. Wages in the oil fields were held at post-World War I levels until workers struck, and rioting swept southern Trinidad in the late 1930s.

The Depression, however, forced a creative idleness on some urban young men in and around Port of Spain—where many of the calinda bands originated. New groups of yard-based Carnival devotees began to experiment with the bamboo bands. They augmented the sound of the bamboo by adding improvised percussion instruments, such as a gin bottle hit by a

Craig Duncan; DDB Stock Photo



Bob Krist

Pan tuner Bertie Marshall, below, uses an electronic instrument to perfect the pitch of each pan. Left: The Casablanca Steel Orchestra in Port of Spain. Below, left: A child plays an old-style toy pan with wooden mallets, whose ends are covered with cloth or strips of inner tubes.

Abigail Hadeed

spoon (the bottle and spoon), a brake drum tapped with a piece of steel, and various metal containers (including biscuit tins, wastebaskets, and any other vessels that gave off a loud sound when pounded by steel).

The Newtown Band, located in a barrack yard in Port of Spain's enclave of Woodbrook, was one of the first of these new bamboo groups. By Christmas 1939, they called themselves Alexander's Ragtime Band after the American film musical released in 1938 and probably shown in Trinidad in 1939 after Carnival. By Christmas 1939, according to calypso singer Roaring Lion's lyrics,

Here the kind of song they sang in
  Town
Christmas night when the bands were
  going around
They had the bottle and the spoon and
  biscuit-pan
Better known as Alexander Ragtime
  Band
And the leggo was,
"Zhuway, zhuway talalee levay"
We know it as job molassie band
Bad behaviour and boboley band
But New Town boys changed the name
And decided to invade Port of Spain
So they marched down Town banner in
  hand
Signed "Alexander Ragtime Band."

The pan bands continued to evolve as Trinidad became enmeshed in World War II. The United States established a naval base and other facilities on the island as a part of the lend-lease agreement with Britain, and American and Canadian soldiers and sailors were introduced to calypso songs. With Trinidad's wartime boom, calypso singers came into their own, although the British tended to discourage festivities.

According to the Port of Spain *Gazette* for February 15, 1940, "a band of about 150 strong was parading Duke Street about 6:30 o'clock in the morning, jumping and shouting to music provided by biscuit drums, bottles and spoons. The police intervened." This was one of the first altercations that collectively became known as the steel band riots. Some of Trinidad's middle class reacted to the poor upstarts (from the districts of Laventille, Newtown, Belmont, or Gonzales) as they had to the riots of the 1880s. Others, including Trinidadian folklorist Canon Max Farquhar, applauded the zest of uneducated people who were "normally shunned as the unwanted and undesirable." The British finally outlawed outdoor Carnival altogether because of the war, so the calypso tent, which often included steel orchestras, became the primary venue for Carnival activities.

With the Allied victories at the end of World War II, pan bands were once again legal, and they flooded the streets of Port of Spain, beginning with V-E Day in May 1945, and V-J Day in August. As Roaring Lion sang it:

V-J Day was a holiday
Black and white start to breakaway
Everyone jump in the bacchanal
Getting ready for the Carnival.

By the late 1940s and early 1950s, the pans of choice were discarded fifty-five-gallon oil drums, which were plentiful in oil-rich Trinidad. Experimentation on tuning the surface of the pan had been going

Groups of up to one thousand or more elaborately costumed dancers compete to be judged the best masquerade band of the year.
Craig Duncan; DDB Stock Photo

on since about 1939. One of the first innovators was Ellie Mannette, a young man from Port of Spain's Woodbrook. After the war, he annealed the drum's bottom, pounded out a series of concave notes in it, and then cut the cylinder to about five or six inches high so that the oil drum's base became the pan's melody-making top. The key pan in the early steel band was the "ping pong," a tenor instrument that could play more than one octave. Several different schemes for arranging notes on the top of the pan were developed but not standardized, although Mannette's was widely copied. In addition to the tenor pan, a cello and a set of three bass pans were used.

Early in 1951, a group called the Trinidad All Steel Percussion Orchestra (TASPO) prepared for a trip to England. TASPO was a smash hit in the mother country, and pan had come of age. As people from outside Trinidad took note of this surprising development in acoustic instrumentation, Trinidadians of all stations began to acknowledge their local invention. Steel orchestras were adopted in Antigua, Jamaica, coastal Venezuela, and elsewhere in the Caribbean. Soon, steel orchestras would be established in many countries throughout the world.

This brings us back full circle to my love-hate relationship with pan. Pan is one of the last of the great acoustic instruments to be created anywhere in the world—the accordion, harmonica, and saxophone being nineteenth-century inventions. For people like me, who like live sound made by real people in real time—as opposed to canned, prerecorded, and overdubbed mechanical music—pan fills the bill nicely. The full sound of a steel orchestra, playing a road march by Lord Kitchener (Alwyn Roberts)—the greatest composer of music for this joyful instrument—on the last night of the last day of Carnival is a singular achievement of human exuberance. Just like highly electronic, overdubbed rock, reggae, and rap, steel orchestras can totally envelop a listener, producing a heightened, but natural (acoustic), experience that is compelling and never to be forgotten. □

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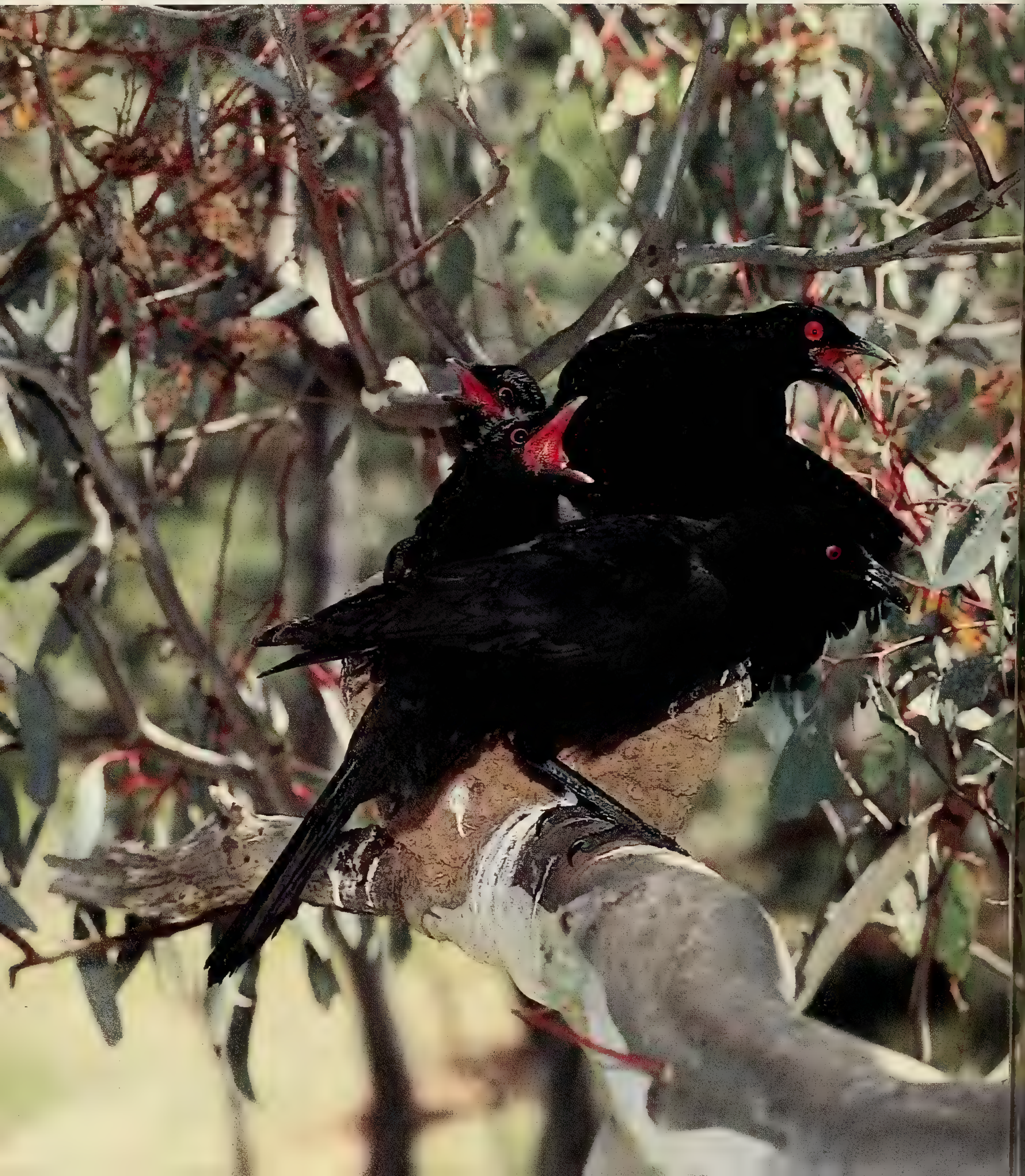
Rai

In Australia's Ainslie Nature Park, adult white-winged choughs tend youngsters in the group nest. Raising a single chick through its first year of life may require the efforts of seven older birds.

C. A. Henley



f the Red-eyed Chicknappers

Kidnapping and adoption are extremely rare in the animal kingdom. Is the behavior of Australia's white-winged chough an exception to an evolutionary rule?

by Robert Heinsohn

Fifteen large black birds, wings waving and red eyes flashing, moved en masse along the ground toward the enemy. Their shrill whistles filled the air like battle cries.

The enemy was a neighboring group of the same species, four white-winged choughs that had just fledged two young. Upon meeting, both groups flew high into a tree, the smaller group leaving its young on the ground. Lined up on opposing branches, the two groups proceeded with their wing-waving, tail-wagging displays, an impressive spectacle in which the white patches on their wings were shown off to their fullest. At the same time, their red eyes turned a deeper color of scarlet and seemed to bulge as the conjunctiva became engorged with blood. While this treetop skirmish was under way, three members of the larger group flew down to the opposing side's young and, using the same displays, enticed one away. The adults of the small group were driven off and made no attempt to retrieve their missing fledgling.

During my four-year study of white-winged choughs (pronounced "chuffs"), I observed four such "kidnappings" at close quarters. In fourteen other instances, I deduced what had happened when youngsters suddenly changed groups or disappeared following an intergroup battle. Based on the social attentions shown the captives, I had no doubt that the fledglings were being actively recruited for membership in a new group. On one occasion the kidnappers started preening their detainee immediately and were feeding it within half an hour. But why would any bird invest effort in unrelated offspring, especially when—as in this case—the young won't become self-sufficient for about eight more months? To understand why choughs kidnap and raise unrelated youngsters—behavior rarely seen outside human society—requires taking a close look at their ecology and unusual social system.

White-winged choughs are crow-sized omnivores that live in social groups of four to twenty individuals. They nest high in eucalyptus trees, but their size, group behavior, and ground-feeding habits make them conspicuous in the woodlands and farmlands of eastern Australia.

Chough family life is unusual; juveniles do not disperse shortly after fledging, but instead stay with their families. When they have begun to master the skills of finding food, they help their parents and other relatives to raise subsequent broods—a strategy known to ornithologists as cooperative breeding.

Most other songbirds reach full adult size in a few months and begin breeding at the latest in their second year, but choughs take an extraordinary four years to mature sexually and to become competent foragers. Although they reach full skeletal size by their first year, young choughs continue to gain weight until their fifth year, when their gonads become fully developed. (They do not get their red eyes until they are adults.) Younger members of the group can help with feeding young, but they are incapable of raising a brood on their own. However, in evolutionary terms, it is worth their while to contribute to the group's reproductive success. By helping family members breed they can insure that more individuals in the next generation carry some of their own genes. Another and more immediate advantage to helpers is that they gain experience in such crucial matters as nest building, recognition of danger, and caring for young.

The difficulty of finding food is central to chough social life. Foraging is a labor-intensive activity (and a somewhat comical procedure from an observer's point of view). The birds wander over very large home ranges in the woodlands, sifting the slow-to-degrade eucalyptus leaf litter and probing the soil in search of insects, worms, and other invertebrates. A chough may spend minutes excavating a cavity up to eight inches deep, often with no reward. The birds seem intent in their quest, tossing leaf litter and soil in all directions with their long, downward-curving beaks. While moving through the sparse understory, they call softly and continuously to maintain contact with the rest of the group.

Individuals often let out a harsh screech if they find a worthy item, say a fat beetle larva, and the younger group members converge on them, begging noisily. Within the eucalyptus forest, a miniature, lunarlike landscape of craters and scattered debris is a sure sign that a group of choughs has passed through.

Younger birds have trouble deciding where to spend their time digging. My research showed that first-year choughs have very poor returns for the time they spend foraging but that their efficiency improves steadily over the next three years. Older individuals have a much better idea of which patches of ground are worth digging in, as well as the experience to know when to give up on an unprofitable site. During the breeding season, choughs spend virtually the entire day feeding themselves and their nestlings, and even after the young fledge, the group still spends more than 80 percent of its time in coordinated foraging bouts. The sight of a dozen black birds systematically fanning out, combing and ripping up the woodland floor, and then (if an intruder is spotted) flying off—wings waving, tails wagging, and uttering their shrill, piping alarm whistle—is one of the great spectacles of the Australian bush.

Cooperative breeding occurs in only about one percent of the world's birds, but is particularly common in Australia. Among choughs, usually only one pair in the group breeds. When a group grows to more than fifteen individuals, four or five are generally fully mature helpers; the rest are immature birds between one and three years old. Larger groups capitalize on hav-

Graeme Chapman

C. A. Henley

A popeyed adult chough, left, feeds a scarab beetle larva to begging young in the communal nest high in a eucalyptus tree. Bottom, left: A chough collects mud to be used in constructing the group nest. Below: After defending its young from marauding neighbors, an adult chough, its back hunched, flies back to its own group.

C. A. Henley

ing extra helpers by producing two broods in a season. Why individuals should forgo breeding and instead stay at home and help others has inspired a lot of debate among evolutionary ecologists. Many feel that young birds are simply constrained, by lack of territory or mates, for instance, from going it alone, and that the next best choice is to help relatives raise their young. Others theorize that in many cases the birds have the option of dispersing, but derive some overriding advantages, such as protection from predators, by staying home.

No one has satisfactorily explained why Australia is a center for so much cooperative breeding, although some recent suggestions are compelling. Australian ornithologist Hugh Ford, of the University of New England in New South Wales, noted that cooperative breeders are most common in eucalyptus woodlands, a habitat without distinct seasons and therefore lacking the resource peaks—burgeoning fresh foliage and flowers and insect flushes—that boost the springtime breeding efforts of Northern Hemisphere birds. A consequence of this low-yield habitat may be that although adult birds have little trouble supporting themselves in a eucalyptus forest, they may have a difficult time finding the extra food required for nestlings. This ecological reality might encourage young birds to stay home and older breeders to recruit helpers. That Australian songbirds generally lay smaller clutches and have longer breeding seasons than their counterparts in the Northern Hemisphere seems to support this view.

White-winged choughs are certainly constrained from breeding on their own while young, and even after reaching maturity must have help from others. In the entire four years of my study and also during a much longer study by Australian ornithologist Ian Rowley, not a single unassisted pair of choughs succeeded in fledging young; even trios failed. Nests were built and eggs were laid, but only breeding pairs with at least two helpers could expect to bring a single young to the point of fledging. The success rate of assisted pairs continued to increase with each additional helper.

Unfortunately, the group's hard work does not stop when a chick leaves the nest. Choughs hatch in early spring and fledge in a helpless state about four weeks later; their flight feathers grow very slowly and the birds cannot fly properly for at least a month. The young then require feeding for another six or seven months, and their needs are especially great during the cool Australian autumn, when insects are not abundant. The fledglings make a very slow and partial transition to independence during this period, for their life support is cut off in winter, when the adults and helpers have enough trouble feeding themselves. Raising one young from the egg to the beginning of the following breeding season takes on average seven choughs.

As there are no spare choughs floating around (remember that they all stay at home), aspiring first-time breeders must find their help from within their own or other groups. One way is to wait for the group to grow very large, say to more than fifteen individuals, when it will break up into factions of four or more. With some jostling for position, older helpers can then become breeders in a new group. Alliances formed within the group serve

A group of adult choughs, below, hunts for larvae and worms in the soil. Such food is scarce in the eucalyptus forest, compelling the birds to spend many hours in daily foraging. Right: Red eyes blazing, adult choughs perform their wing-waving display for a begging fledgling. On the ground, bottom right, an adult bird feeds a youngster. Immature birds often take three years to become skilled at finding food.

Photographs by C. A. Henley

breeders well when the group splits, for one very effective way of winning the loyalty of other individuals is to care for them as nestlings and fledglings.

The majority of helpers are recruited from within the group. Often the young from previous years help to rear their siblings. With competition for allies within the group so rife, however, individuals also look outside for new recruits. For the necessary extra help, the group must go in for kidnapping. Battles between groups occur daily, both before and after fledging young; small groups must constantly defend their young from the pirating activities of their marauding neighbors. Kidnapping can occur even before a youngster can fly well. When enticed away, the fluttering detainee can be herded along the ground, or its parent group can be driven off. Of the fourteen "chicknapping" cases I was aware of, six young disappeared from their new group without a trace, three returned (escaped?) to their original group within a week, and five were alive and with their new group the last time the group was located. I observed three that had survived in their new groups for more than a year, and I was able to watch all of these helping at the nest.

Aggression between groups is not limited to kidnapping raids; nests are also targeted. Choughs begin nesting late in the southern winter, and they need three to four days to build an elaborate mud nest high in a eucalyptus tree. By the time the dried nest is finished, it is about one foot in diameter and may weigh more than five pounds. (Some are so perfectly round they look as though they have been turned on a potter's wheel.) On one occasion, one of the smallest groups under my surveillance (it had only four members) started nesting two weeks before its neighbors. This early start was not advantageous, however. The group was repeatedly harassed by other groups and often had to huddle around the nest to prevent the opposing group from landing on the rim and pecking at the mud. The nest was eventually dislodged this way, and the small group did not fledge young successfully until its fourth breeding effort.

Even though I commonly saw choughs destroying nests, it wasn't until I saw another startling behavior that I knew with certainty that these birds actively aim to delay each other's breeding. To get precise data on chough reproductive rates, I had been using a mirror mounted on a pole to count eggs in nests. Once when I was using this technique to study a group of eight choughs, they became distracted, and another group of five flew to the rim of the nest. One individual, which I could recognize as an adult by its bright red eyes,

proceeded to pick up the eggs in its beak one at a time and toss them to the ground. It destroyed three out of four eggs this way before being evicted by the residents. Interestingly, some other cooperatively breeding birds—acorn woodpeckers, for example—also indulge in egg tossing. But in such cases, the competition is between individual breeding females within the same group.

Why should choughs be so bent on the destruction of their neighbors' nests and eggs? Choughs are not territorial. Food is too sparsely distributed to be defendable, so feeding ranges overlap, and nests may be built very close to one another. Having another breeding group nearby places a heavy drain on total resources, especially when the rival group includes demanding nestlings.

One quick way to reduce that competition is to disrupt the progress of neighbors' nests, thereby delaying their period of peak resource use. Nest building, although not a lengthy procedure, requires mud and usually can take place only after heavy rain. A broken or destroyed nest may be irreplaceable for long periods, and breeding may be indefinitely postponed. Thus, choughs post sentries to guard the nest—protection against both predators and other groups of choughs.

All the problems choughs face in raising young and competing with others are ultimately linked with the difficulties they have in finding food. Their time-intensive and skill-dependent foraging appears to have shaped their social behavior. And their intense need for helpers, I believe, has led to the extreme behaviors of kid-

Adult choughs face off prior to beginning their spectacular aggressive displays.
A. and K. Tatnell

napping, egg dumping, and nest sabotage.

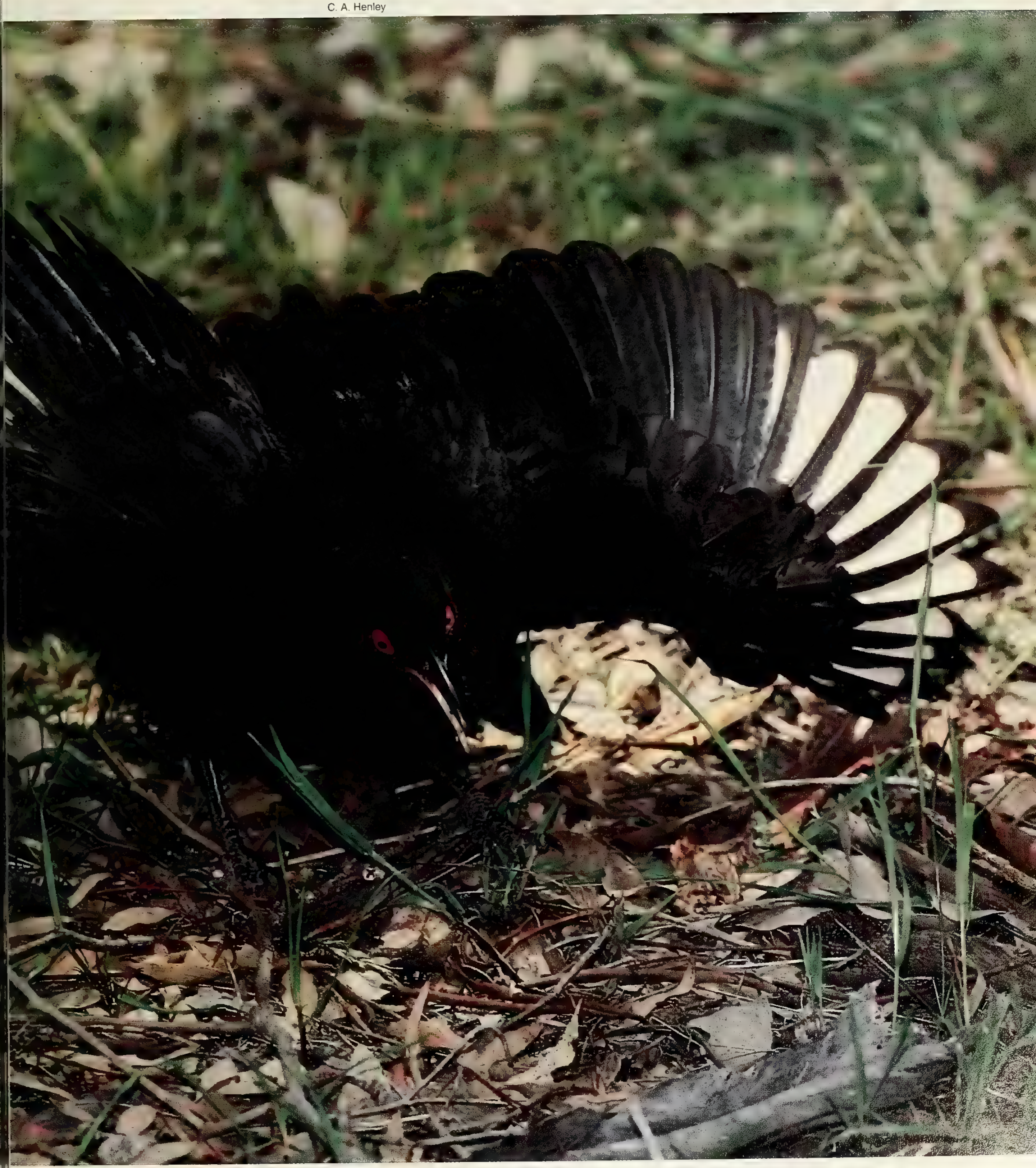
While my field research produced many insights into the choughs' social patterns and ecology, my greatest pleasure was in getting to know some of the birds' individual personalities. (Too often, I feel, animals are treated merely as numbers and averages, when so many of the interesting aspects of natural behavior are due to individual differences.) Three choughs in particular are firmly etched in my memory, identified by the colored plastic rings that I placed around their legs. First is Blue-blue-blue, the first chough I ever banded, a breeding female that became so tame she would take food from my hand and let me count the nestlings under her without even a peck from her sharp beak.

Second is Green-green-orange (GGO), who was almost responsible for my death. Her group built their nests higher than any other group, consistently at least sixty feet off the ground. GGO did not like nest marauders. Every time I climbed to her group's nest, GGO would fly at me furiously. Twice she knocked off my protective helmet, forcing me to abandon my quest to examine her nestlings. On the near-fatal occasion, she flew at me with such vehemence that I leapt back, breaking the branch from which my rope ladder hung. I plunged about twenty feet, my life flashing before my eyes, when the rope again caught on a branch and I was saved by my harness.

Finally, the thought of a yellow-banded chough that I saved from certain death always makes me smile. When he was only a week out of the nest, Single-yellow had fallen and knocked himself out. I rescued him and returned him to his group. But as I watched his inept antics, I realized that he might be a liability to his family. He had no concept of danger, totally ignoring dogs and cats, but sounding a shrill alarm when he spotted harmless pigeons and rabbits. During his second year, the breeders in his group had just sculpted a fine mud nest. Single-yellow spied the nest, gave a great squawk of excitement, and flew over to investigate. Since it was not yet dry, the entire structure collapsed under his weight when he landed on the rim. After that, I abandoned any hope that this chough was just going through an awkward stage. Single-yellow was the best candidate I've ever seen for natural selection weeding out the unfit before they can pass on their genes. But it was time for me to leave the field, and I don't know how long he lasted in the chough's difficult, competitive world. □

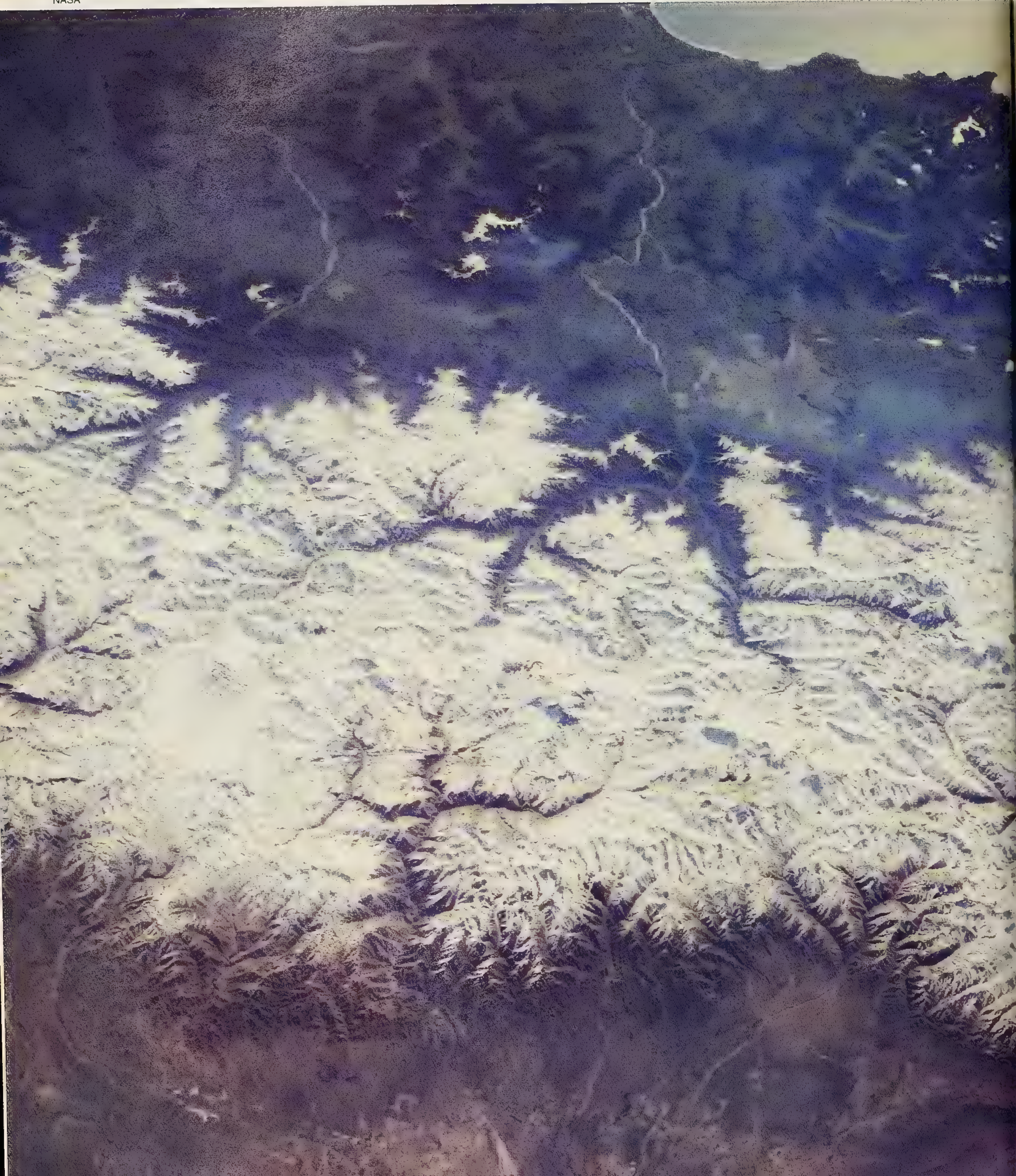
At the height of its performance, a chough, its scarlet eyes bulging, repeatedly flashes its white wing patches.

C. A. Henley



In this westward view from the space shuttle, the snow-covered Andes mark the border between Chile and Argentina. Darwin traversed the range via a high pass linking Santiago, Chile (light patch near the center), with Mendoza in Argentina.

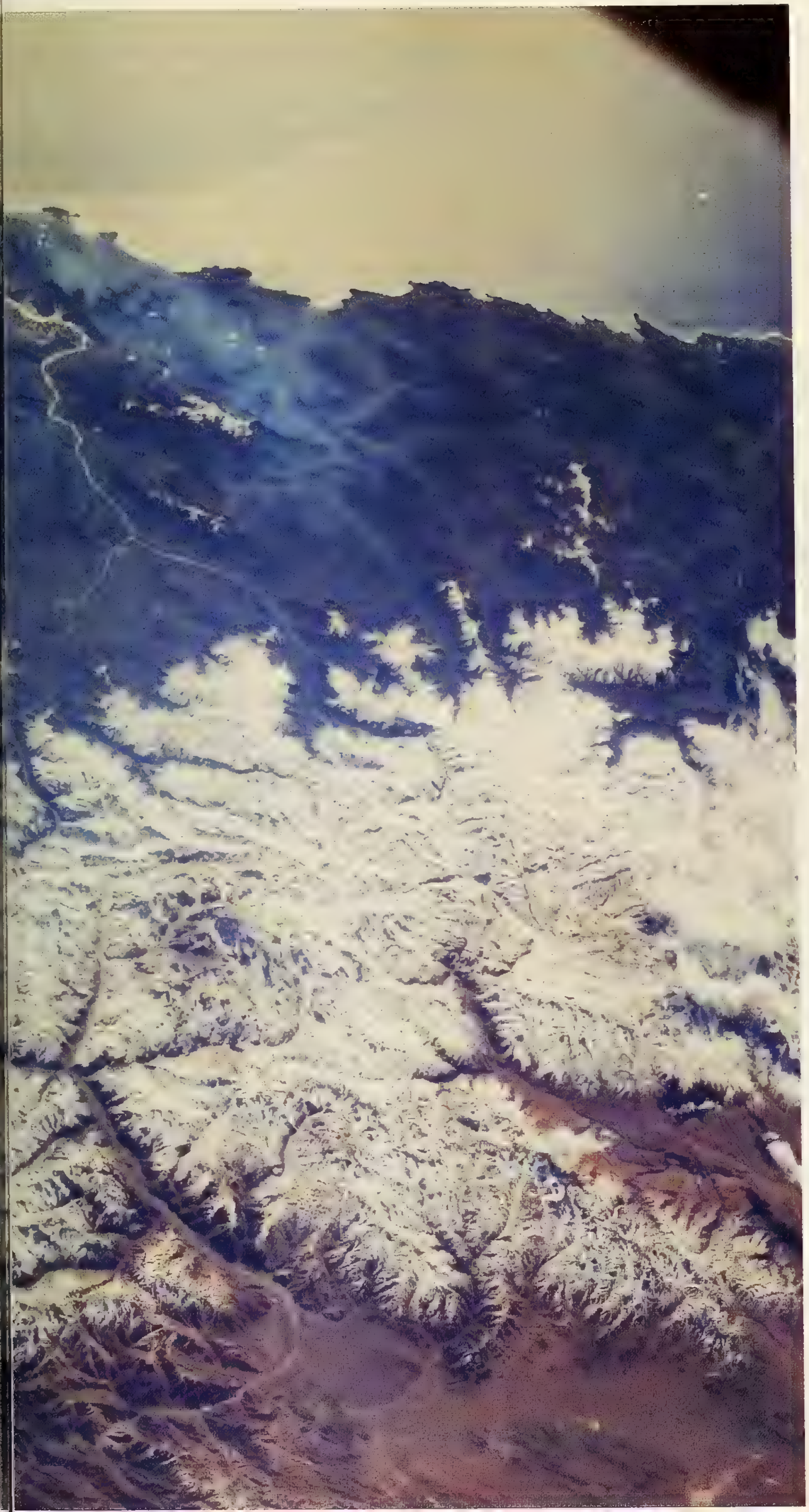
NASA



The Andes' Deep Origins

Peering into the mantle, geophysicists are now able to detect the currents of rock that shape the Andes and other major features of our planet

by Raymond M. Russo and Paul G. Silver



On February 20, 1834, Charles Darwin was taking a noontime rest in a forest not far from the small Chilean coastal town of Valdivia when the ground began to shake. The motion continued for two minutes, and although he was able to stand up, the sensation of the earth rocking beneath his feet made him feel giddy—as though he were back aboard the *Beagle*. Twelve days later, Darwin arrived in Concepcíon, farther up the coast near the epicenter of the quake. He was stunned by the utter devastation that had befallen the town. Only thirty-five lives had been lost, but nothing was left standing. "It is a bitter and humiliating thing to see works, which have cost men so much time and labour, overthrown in one minute; yet compassion for the inhabitants is almost instantly forgotten. . . . In my opinion, we have scarcely beheld since leaving England, any other sight so deeply interesting."

Darwin also noted that shells of recent marine species had been uplifted with the land along much of Pacific coast of South America. With the same insight that he brought to the biological world, he concluded that "the elevation on this western side of the continent has not been equable. . . . At several places the land has been lately, or still is, rising both insensibly and by sudden starts of a few feet during earthquake-shocks; this shows that these two kinds of movements are intimately connected together."

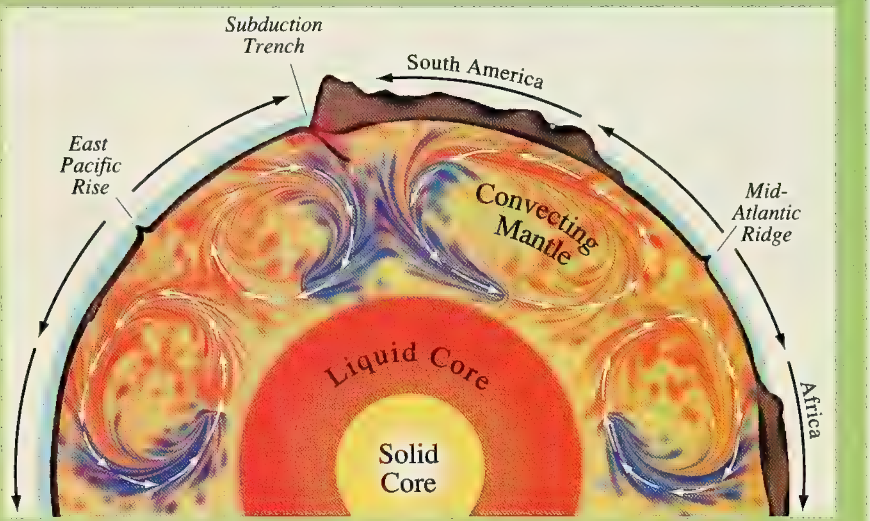
Both the lofty peaks of the Andes, many rising above twenty thousand feet, and the violent earthquakes that made such a strong impression on Darwin are spectacular evidence of plate tectonics. Since Darwin's time, the motions of the dozen or so thin, rigid plates that pave the earth's surface have been largely worked out. Recovering from a wound received early in World War I, Alfred Wegener, a German scientist and explorer, developed the idea that the continents were once assembled in a single landmass called Pangaea and were now drifting apart. For lack of proof, his work was not taken seriously, but in the years following World War II, surveys using a variety of new technologies gave geologists their first detailed

Illustrations by Joe LeMonnier

look at the ocean floor—two-thirds of the earth's surface that was previously uncharted. In a burst of creative insight in the mid-1960s, geologists realized that ocean crust was being created along the mid-Atlantic ridge, and as this new crust spread outward, it carried continents along with it. Meanwhile, the Pacific Ocean floor was being continually renewed as new crust was being formed and older crust was destroyed. With the plate tectonic revolution, many of the earth's features suddenly made sense.

The earthquake Darwin experienced, for example, resulted from the convergence of two plates: in the slow-motion crash, the Nazca plate slid, with some resistance (hence the violent tremors), beneath the South American plate and was subducted, or forced down, into the mantle. The descending ocean plate, overridden by the lighter and thicker continental crust, disappeared along a deep trench in the ocean floor paralleling the Pacific coast of South America.

Mantle Convection: Making the Earth Move



Cut the earth in half and you will find mostly mantle rock. It surrounds a large iron core and is itself covered by a thin crust. The crust is divided up into about a dozen plates which are in constant motion, diverging along midocean ridges and colliding along deep sea trenches. The jostling of the plates, which produces most of the large features on the earth's surface, is caused by currents deep within the mantle.

Despite the mantle's rocky composition, it flows—albeit at a rate measured in inches per year—and heat is what keeps the oceans of rock slowly churning. Some ten to fifty miles down, depending on where you are, the mantle gradually gives up its stored heat to the rigid crust, which then conducts the heat upward to the atmosphere, where it is lost. As the mantle rock near the surface slowly cools, it becomes denser than the surrounding hot mantle and eventually sinks. At the same time, the deepest portions of the mantle are warmed from below by heat from the earth's core and by the steady decay of radioactive elements in the mantle itself. This deep mantle rock becomes buoyant and rises in an upwelling mass. These two processes occur simultaneously in the mantle, so that it circulates in discrete masses called convection cells, which are shown above in generalized form. (You can watch similar convection cells form in a cup of hot, unstirred coffee with milk, or better yet, hot miso soup served at any Japanese restaurant.)

Although the theory of plate tectonics has explained a lot, the forces that drive the plate motions have remained unobservable, buried deep in the earth's interior. From very early on, geologists had assumed that the circulation of the mantle rock, flowing at a snail's pace in vast gyres, was intimately connected to plate motions, but the nature of the relationship remained murky.

In the case of the subducted Nazca plate, geologists assumed that it marked a region of sinking mantle and that at least some of the mantle was welded to the descending plate. The coupling of plate and mantle was presumed to be more or less complete in most cases: where the mantle went, so went the plates. Thus plate motions, and in particular the locations of subducting slabs, were thought to be our best indicators of mantle motions.

Within the last few years, however, a newly observed phenomenon called shear wave splitting has allowed us to determine the orientation of mantle flow using data from waves propagating outward from earthquakes. To test the technique on a continental scale, we decided to study the mantle beneath the Nazca subduction zone along the western edge of South America. We chose the coast because, first, it is a convenient place to put seismometers (many subduction zones are deep under the ocean). Second, the coast has plenty of earthquakes and therefore lots of earthquake data to "illuminate" the mantle below. And finally, because the motion of the two plates was particularly simple (the Nazca plate is moving essentially eastward at approximately 2.5 inches per year, and South America is moving westward at a little more than an inch per year), we expected the mantle flow to be simple, too. We were confident that the mantle beneath the Nazca plate would be flowing from west to east, and that it would be strongly coupled to the descending slab.

Some 350 seismograms later, we knew

that the orientation of mantle flow beneath the descending Nazca plate was not what we had expected. We found a varied pattern of orientations, but most were *parallel* to the curvaceous western coast of South America and the subduction trench. We were flabbergasted. How could all those ideas on plate and mantle motions be wrong? Could the mantle be moving largely independently of the Nazca slab, often at right angles to the eastward motion of the oceanic plate? After double-checking our results and finding that they were correct, we realized that we would need a new model of the mantle flow and plate motions to explain what we were observing.

The westward motion of South America was the key to our new model. As the continent moves, it pushes the Nazca trench and the entire subduction zone westward before it. What if, as it is pushed westward, the descending Nazca slab is pushing the mantle out of the way like a continent-sized snowplow?

If true, this model implies that the mantle is not welded solidly to the descending slab, but is instead free to flow in any direction—as long as the way is clear. Because the descending slab represents an impermeable barrier, angling downward into the mantle to depths of 400 miles or more and extending the length of South America's western margin, we would expect the mantle to flow in any direction necessary to escape the slow westward push of South America.

But what we observed, mantle flow oriented parallel to the coast, indicates that the mantle under the slab does not move downward with the plowing slab. We suspect that it is prevented from descending

Mapping the Mantle Flow

We can "see" deep inside the earth with the help of seismic waves emanating from earthquakes (and the occasional underground nuclear test). The energy from such shocks is transmitted easily through rock, which deforms briefly and snaps back into shape as seismic waves pass. When the waves arrive at the surface, they carry a great deal of information, not only about which path they traveled but also about the properties of the rocks through which they passed. If the waves can be recorded with fidelity and interpreted with sophistication, they can reveal aspects of the earth's interior in some detail.

In 1909 an earthquake shook the Balkans, and Andrija Mohorovicic, a Croatian geologist, used seismographic recordings of the event, scribbled on a rotating drum of paper by a trembling needle, to infer the upper boundary of the mantle. He found that the crust beneath his feet extended only twenty miles down. (We now know that ocean crust is usually between three and four miles in thickness, while the continental crust averages about eighteen miles. The thickest crust, extending as much as forty miles down, lies beneath high mountain ranges.) In 1914, Beno Gutenberg, a German-born geologist, detected the lower boundary of the mantle where it contacts the core at a depth of about 1,800 miles.

Further seismic work revealed sharp physical and chemical boundaries within the mantle as well. The uppermost layer appears to be relatively rigid and welded to the crust to form the plates, or lithosphere, some forty-five miles thick. A more ductile layer of mantle, called the asthenosphere, lies below the plates, and at a depth of about 155 miles, it passes into the mesosphere, the solid, increasingly dense bulk of the mantle, which extends to the earth's outer liquid core.

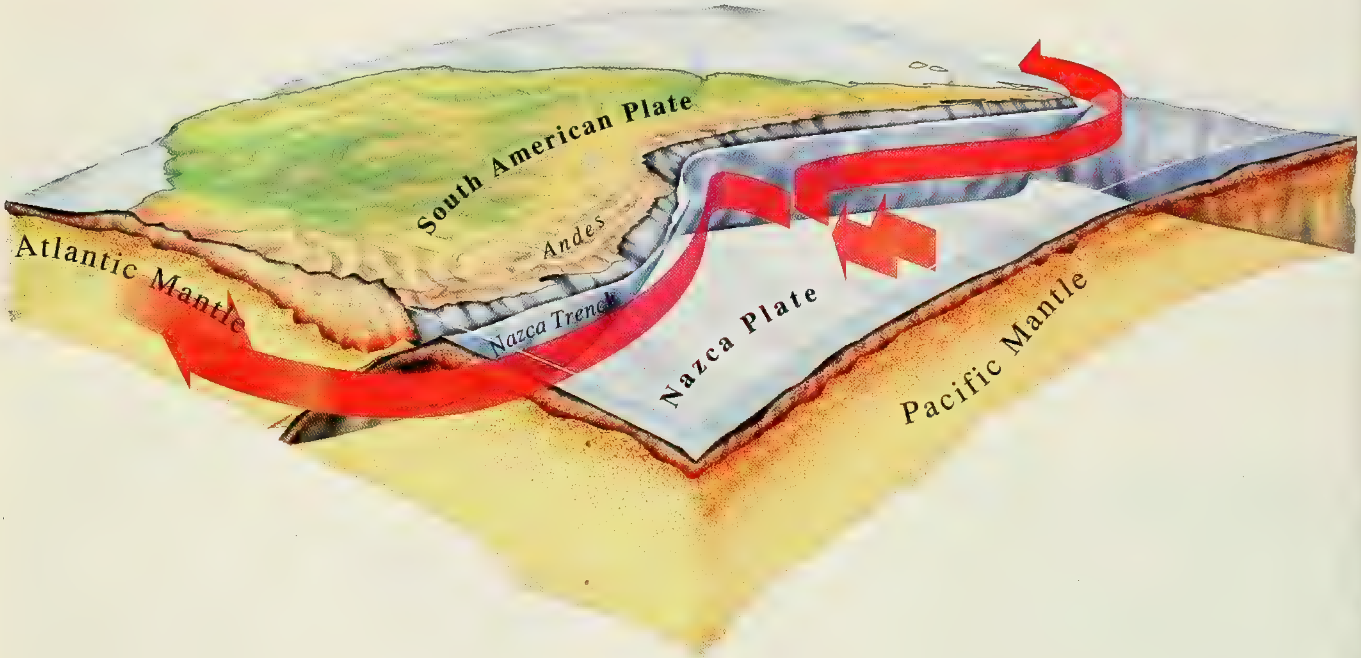
In the 1980s, geophysicists began using seismographic networks and fast computers in an attempt to see more features in the mantle. Thousands of seismic waves were analyzed, using tomography to generate something like a CAT scan of the earth. Because seismic waves generally travel faster in cool mantle rock than they do in the warmer regions, these images reflect temperature patterns in the mantle and can be used to infer convection, usually with hot, rising regions shown in red and cooler, sinking mantle depicted in blue. But such images are rough and tell us little about the direction in which the rock is flowing directly beneath the plates.

To see such regional details, we make use of a curious phenomenon displayed by olivine, the predominant mineral in the upper mantle, and a particular type of seismic waves called shear waves. Like other minerals, olivine vibrates from side to side as shear waves pass, but because of the peculiarities of its crystal structure, the waves are often "split" in two, with one traveling faster than the other, a phenomenon known as seismic anisotropy (which simply means that the mineral does not transmit seismic waves the same way in all directions). The degree to which the waves are split depends on the orientation of the long axes of the crystals relative to the seismic waves striking them. The "polarization" of the twin pulses is similarly dependent. Because both of these effects can be measured at the surface with modern seismographs, we can determine the orientation of the olivine crystals deep within the earth. This, in turn, can reveal which way the mantle is flowing.

At the high temperatures and pressures within the earth's mantle, olivine crystals slowly change their shapes and orientation in response to stresses associated with mantle convection. Over time, the long axes of the crystals align themselves parallel to the direction of flow. And because mantle convection is really the large-scale, organized flow of countless crystals, large regions of upper-mantle olivine point in the same direction and more or less behave seismically like a single, very large crystal. By determining the regional orientation of olivine crystals, therefore, we map the orientation of mantle flow and can begin to understand how it influences plate motions.

The mantle under the Nazca Plate flows east until it reaches the Pacific coast of South America. There, blocked by the subducted portion of the plate, it pushes against the Andes and then flows parallel to the obstruction until it can escape around the northern and southern edges of the continent. Simultaneously, South America, the Nazca trench, and the subducted plate are pushed westward by the Atlantic mantle.

Evidence of mantle flow around South America can be seen in the surface topography. The southern tip of the continent is curved to the right at Tierra del Fuego, and the Scotia Plate is pushed out into the Atlantic. In the north, a similar feature is formed by the Caribbean Plate.



deeper than 400 miles because an increase in mantle viscosity at this depth may prevent the flow from descending into stiffer mantle, or a pressure-induced change in the structure of mantle minerals, which occurs at this depth, may cause the top of the mantle to be much more buoyant than the denser, lower mantle.

Our measurements of seismic anisotropy reveal only the orientation of the mantle flow, not its direction. If we know, for example, that the orientation of the flow is north–south, we cannot be sure whether the direction of flow is north or south. But once again, the motion of South America resolves the problem. As the continent pushes westward, shoving the descending slab into the oncoming flow, the mantle backs up, especially near the middle of the coastline, far from the edges of the slab where the flow can escape. This pressure buildup should occur beneath the coastline at the border of Peru and Chile.

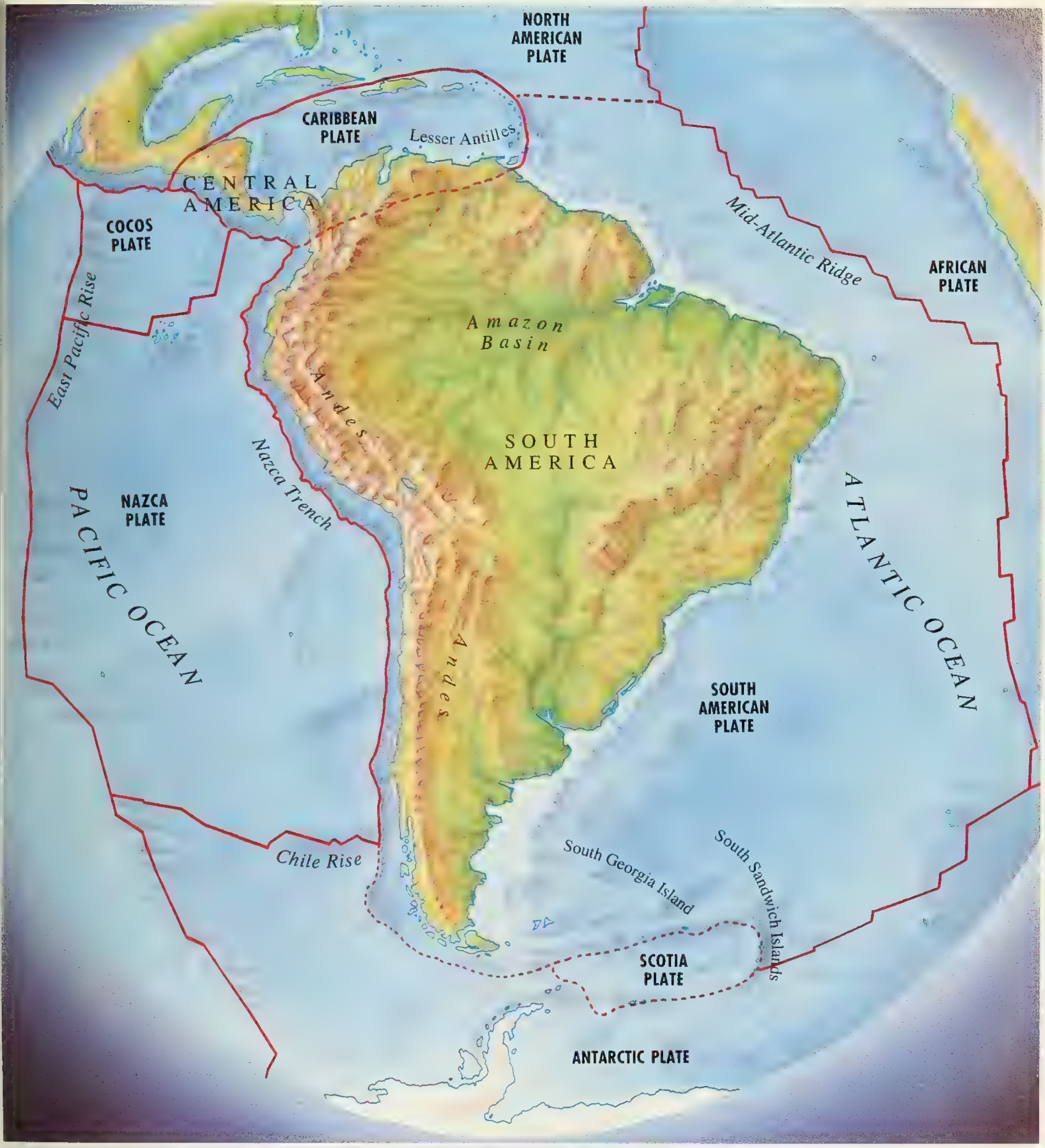
We suspect that the pressure that the flow exerts on the Nazca slab is transmitted to the leading edge of South America. And halfway down the coast, where the pressure is greatest, the Andes are the most deformed, in both horizontal shortening and vertical uplift. The great bend in the mountain chain is probably also a consequence of the great pressure; the leading edge of the continent is buckled inward in response to the impact of mantle flow. Because the flowing mantle is extremely viscous, the pressure beneath the Nazca slab may be transmitted backward to regions of the mantle beneath the unsubducted portion of the Nazca plate. The relatively shallow ocean floor off the coast of Peru is probably a result of the mantle billowing up, floating the crust higher.

From this point of high pressure in the mantle, the flow should diverge, heading northward to Colombia and southward to Patagonia, the tail of South America. And indeed this is what we observed; beneath the Caribbean and Scotia Sea plates that lie north and south of the continent, the mantle flow resumes its east–west orientation as it moves around South America.

The similarities between the Caribbean and Scotia Sea plates—in shape, area, and symmetry—have long intrigued geologists. In Alfred Wegener's third edition of *The Origin of Continents and Oceans,* he speculated that the Antilles and the South Sandwich Islands were moving westward more slowly than the westward drifting Central and South America: "Smaller portions of the blocks are left behind by the westward wandering of the larger blocks. . . . The Lesser and Greater Antilles lag behind the movement of the Central American block, and similarly the so-called arc of the South Antilles [South Sandwich Islands] between Patagonia and West Antarctica."

An important point that Wegener did not consider is that all the subduction zones around the Pacific Ocean, the so-called ring of fire, are retreating toward the center of the Pacific Basin. The oceanic plates now in the basin will eventually be consumed by subduction, and the ocean itself will close. Seen in this light, the mantle flow around South America represents a transfer of mantle from a shrinking Pacific reservoir to a growing Atlantic reservoir. A decade ago, Walter Alvarez (the geologist famous for his impact crater theory of dinosaur extinction) postulated that such channelized flow was draining the Pacific mantle.

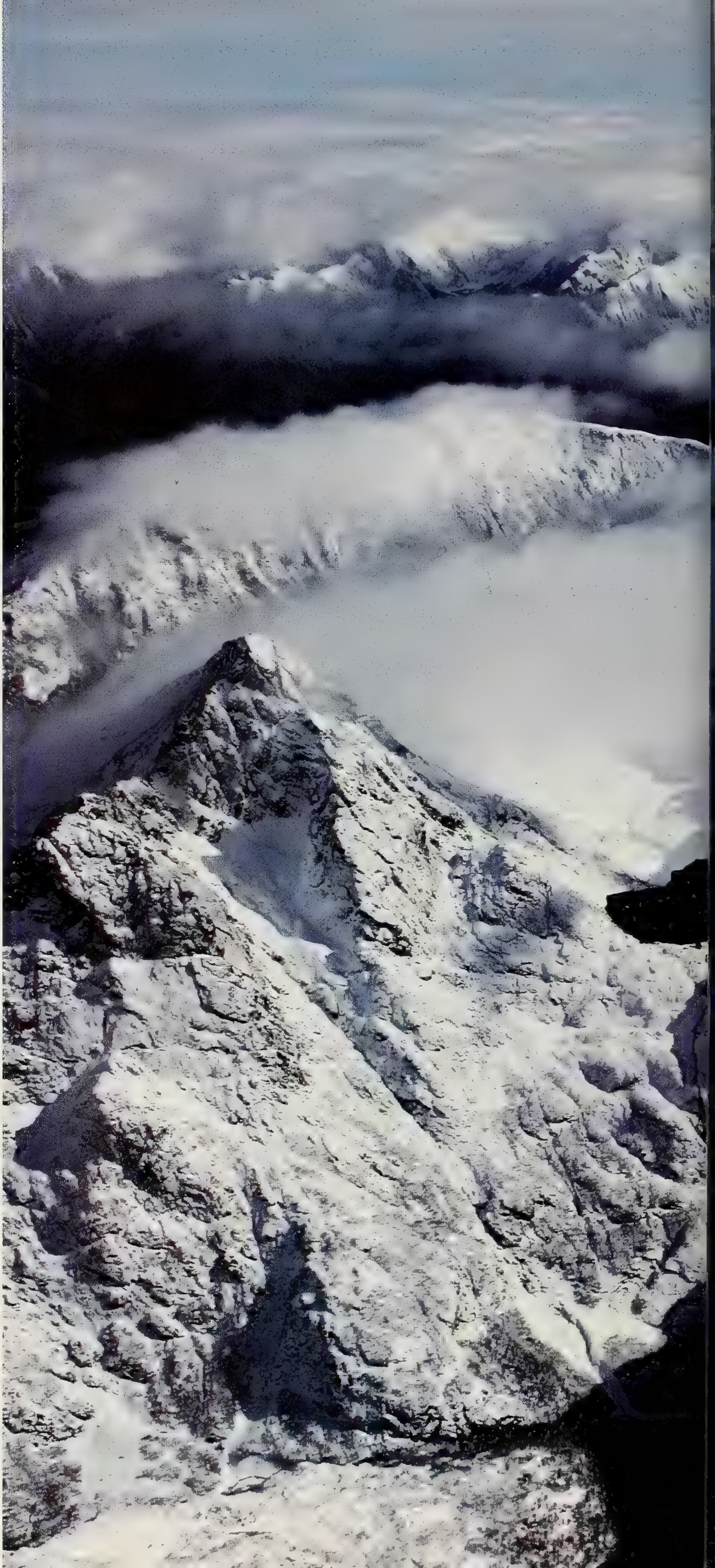
The westward motion of South America, "upstream" through the mantle flowing around it, is the best evidence we have


NORTH AMERICAN PLATE
CARIBBEAN PLATE
Lesser Antilles
CENTRAL AMERICA
COCOS PLATE
East Pacific Rise
Mid-Atlantic Ridge
AFRICAN PLATE
Amazon Basin
Andes
SOUTH AMERICA
Nazca Trench
NAZCA PLATE
PACIFIC OCEAN
ATLANTIC OCEAN
Andes
SOUTH AMERICAN PLATE
Chile Rise
South Georgia Island
South Sandwich Islands
SCOTIA PLATE
ANTARCTIC PLATE

of deep mantle flow driving the plate motions. But how does the mantle push the plate? Geophysicists have long suspected that South America (as well as other continents) has a peculiar deep "root," made of strong, cold mantle welded to the continental crust east of the Andes. We speculate that this root may actually extend deep enough to be swept up in, and pushed along by, deep mantle flow, rather like the keel of an iceberg. If this is true, then the deep mantle beneath South America must be flowing westward, pushing the continent and driving the Nazca slab backward. The Andes form because the leading edge of the continent is weaker and more easily deformed than both the mantle beneath the core of continent to the east and the Nazca plate and its underlying mantle to the west.

North America is probably propelled westward by the same deep mantle flow generated beneath the opening Atlantic. Wegener had postulated a connection between the motions of North and South America and the formation of the mountain chains running along their western coasts: "By the westward drift of the two Americas their anterior margin was folded together to form the mighty range of the Andes (which stretched from Alaska to Antarctica) as a result of the opposition of the ancient well-cooled and therefore resistant floor of the Pacific."

Wegener was remarkably prescient in relating the deformations of western North and South America, even though his de-



In the Argentine Alps, a high mountain lake is nestled among rugged peaks, some of which reach more than 20,000 feet.
Nicholas Devore, III; Photographers/Aspen

formation mechanism, the resistance of the "floor of the Pacific," has since been superseded by the recognition of long-lived subduction zones. The connection between the westward motions of North and South America and the geology of the Rocky Mountains is clearly indicated in the similar shapes and great width of the Rockies and the Andes. Like the Andes, the Rockies are sharply bent. The range, which follows a northerly trend through New Mexico and Colorado, bends in Wyoming to take a northwest trend from Montana north. Also, the Rockies are widest and most deformed and uplifted in this central region. But the Rockies are a much older chain than the Andes and have since suffered several important tectonic episodes that have obscured the telltale embayment that may have existed along western North America during their formation. A jumble of exotic terrains (some of which resembled island chains such as the Philippines) were swept up and accreted to the western edge of North America as it advanced. The Basin and Range province, comprising much of the southwestern United States, formed as subduction ceased beneath western North America. Even later, the San Andreas fault system, a narrow corridor along which the Pacific and North American plates slide past each other, developed in California.

As seismic waves ripple through the earth, they give us new insight into the mantle forces that ultimately cause the tremors. Our initial observations of mantle flow beneath the subducted Nazca plate have already explained such intriguing features as the symmetry and motions of the Caribbean and Scotia Sea plates relative to South America, the bend in the Andean mountain chain (as well as its great elevation and width), and the anomalously shallow water depths of the Pacific Ocean over the Nazca plate. Most importantly, we can finally show that the motions of at least some plates are driven by an active mantle, and that flowing rock deep in the earth is responsible for the large-scale geological features we observe on the North and South American continents today. ☐

Heavenly Messengers

Is Mother Nature trying to tell us something?

by Roger L. Welsch

Don't look now, but I think we're about to get our comeuppance. After millennia of pretty much having our way with nature, I have the uneasy feeling that nature has had about all it's going to take and that we're in for some unpleasant times. In part I'm talking about the ways in which our tamperings with nature carry with them certain negative effects. A landscape denuded of its forests or jungles or grasses doesn't just sit there smiling. As we can see happening right before our eyes again and again, the consequences include such unpleasantries as raging fires, mud slides, dust storms, and shopping malls.

There are also killer bees invading California (where they are known as involuntary manslaughter bees), fire ants in the South, Lyme-disease-bearing ticks in the North, rabid skunks in the West, disease-carrying mice in the Navajo Southwest, president-attacking rabbits in the Southeast, and on and on. This is more than tit for tat. I think Mother Nature has drawn some conclusions about how things are going, and this mother ain't the least little bit happy.

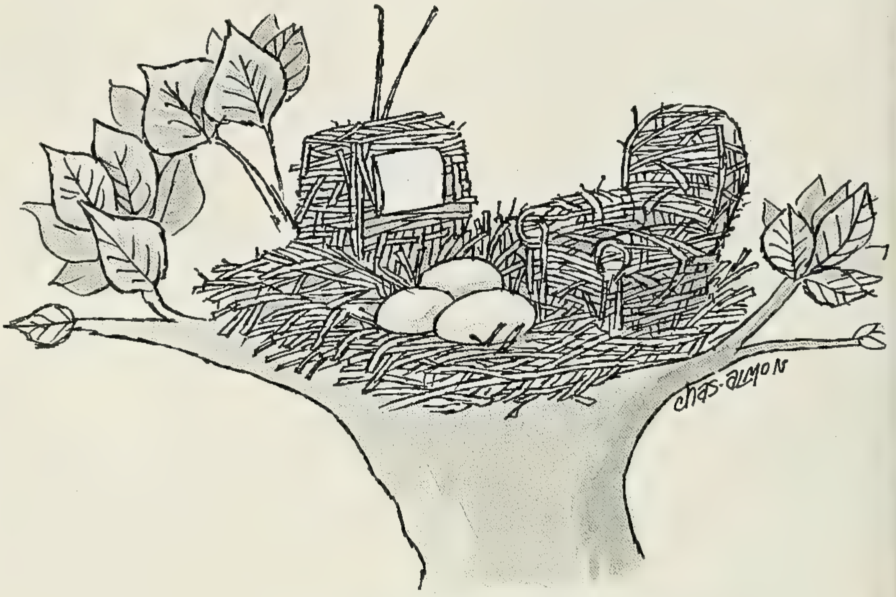
Take birds. Who has not lounged prostrate on lawn or couch and contemplated the wonder of flight and song provided us by gentle, wing-ed fowl? (Birds have always had this innate ability to make human beings talk goofy.) I have been pecked by mad hens and goosed by geese, but that is in the nature of the hen and goose. Neither am I talking about New Guinea's pitohui, known to locals as a rubbish bird, which is not only poisonous to eat, but poisonous to touch! (In my opinion, any bird that is called a rubbish bird and has been given a moniker that for all the world sounds like a watermelon-seed spitting contest has every reason to be toxic.)

I am talking about birds in general. And a specific behavior. I suppose, given the number of birds in the air and the number of people on the ground, a certain number of human heads are going to be pooped on by birds. I have surveyed the literature, and while even the most careful diarists and chroniclers make no note of it, I think it is altogether likely that throughout history, everyone, from popes and kings to plowmen and mammoth slayers, has been surprised from an ether in which no airplanes flew.

I recall with particular pleasure and awe the time—some of you may have to ask your parents or grandparents what this next phrase means—when my father and I were working in our Victory Garden. A bird pooped on his head, and it was mulberry season. I expected Dad, standing there looking for all the world like Gorbachev, to explode in fury, but without a word he pulled his big, red kerchief from his back pocket and mopped his stained brow, only then looking skyward and saying quietly, "For the rich, you sing."

One of the things that seemed funny to me about the situation was that Pop attributed intent and prejudice to what was clearly a random accident. Increasingly, I'm not so sure. Not long ago I was speaking at Swedish Days in the little town of Stromsburg, Nebraska. The day was pleasant, and so the gathering was held outdoors. The fellow in charge asked me what he could do to make me comfortable as I spoke, and I said that I would like a cup of ice and soda, and laughed, "Maybe you should get a cover on it so a bird doesn't poop in it while I'm speaking!"

Hahahaha. Well, the guy forgot the cover, and sure enough, I was standing there talking with the cup in my hand, saw a flash of something pass inches from the end of my nose, and felt the slightest tug of weight in the cup in my hand. Now, if you



The nest led researchers to believe the birds had been raised in captivity.

believe that sequence of events was coincidence, then let me try again.

I was standing on the corner of 14th and R in Lincoln, Nebraska, with my friend Rod Schulling once. (I provide the precise, factual details to stress that the events to be described are not the product of a rich imagination or faulty memory.) And a bird pooped on his head, as often happens. Not "as often happens" in the sense of "as often happens to anyone," but with the meaning "as often happened in those days to Rod Schulling." Birds had it in for Rod, and I'd rest my case right there, but many of you would still mumble, "Coincidence, coincidence."

We laughed the insult off (I perhaps more enthusiastically than Rod), I looked up at the bird on the wire thirty feet above and expressed some sort of admiration for the bird's aim and judgment, and we moved about twenty feet along the curbing to resume our conversation.

And blootch! Rod was hit again. I looked up, this time more in wonder than amusement, and said, "Rod, I think it's the same bird." We moved another twenty feet, and this time I kept my eyes courageously skyward. I am not kidding you, that bird hopped along the telephone wire, stopping directly over Rod again. I suggested that for the sake of science Rod stand still so we could continue the experiment, but he declined. Nonetheless, I think the pattern was clear: that bird knew precisely what it was doing.

My own experience is necessarily limited, since it is only mine, but my impression is that the percentage of heads hit these days is increasing well beyond random chance. Ask around. Judge for yourself. But while you're thinking, don't look up. All they need is an excuse.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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Balinese Imaginings

Paintings collected by anthropologists in the 1930s reveal the pervading anxieties of an Indonesian people

by Hildred Geertz

In the early 1930s, two European artists who were living in Bali, Walter Spies and Rudolf Bonnet, persuaded several of their Balinese acquaintances to try their hand at painting. They provided the young men with paper, pens, and brushes, and later helped market their paintings to Western travelers. Tourists bought these up eagerly, so the young men created more and taught their friends the new craft as well. They drew tropical landscapes of rice paddies and volcanoes, Hindu festivals, stylized dances, and busy villages—all the spectacles that foreigners saw and enjoyed. They also observed one of the defining rules of tourist art, depicting only a traditional world and not the cigarettes, Western clothing, and automobiles that were, even then, familiar to the Balinese.

In 1936, anthropologists Gregory Bateson and Margaret Mead arrived on the island with plans to spend two years studying the nature and formation of Balinese character. Mead, an American, and Bateson, an Englishman, had met while doing research in New Guinea and had worked out a theory of human personality types and their relation to cultural differences. Bali, they had decided, would provide a good test case of their theory. They contacted Spies, who was doing an ethnographic study of dance and drama in Bali, for help in locating a suitable site for their fieldwork.

When Bateson and Mead disembarked, they at once motored over Bali's central volcanic massif to Spies's hill village home in Ubud, where they stayed for two months. Spies was quick to introduce them to the new Balinese paintings. Those from the lowland village of Batuan attracted the anthropologists' particular attention, and they quickly decided to make a side study of the paintings and their makers, hoping thereby to gain additional insight into the inner feelings of Balinese. During the period of their research, from 1936 to 1938, with a brief visit in 1939, Bateson and Mead collected 1,288 pictures, of which 845 came from the village of Batuan.

The people of Batuan may have felt that the anthropologists were just a different kind of tourist, but since Bateson and Mead learned their language and insisted on being told the folktales and myths that some pictures illustrated, the artists were probably stimulated to portray complex themes and ransack their cultural heritage for ever new sources of images and stories. Since they intended to analyze the paintings from a Freudian point of view, scrutinizing them for projections of unconscious wishes and conceptions of bodily processes, the anthropologists tried to avoid influencing the painters.

The exhibition **Images of Power: Balinese Paintings Made for Gregory Bateson and Margaret Mead** will be presented at the American Museum of Natural History from February 3 to May 3. It features more than one hundred depictions of folktales, dreams, and spiritual lore that novice artists created for the anthropologists in the 1930s. Following its opening engagement at the American Museum, the exhibition will travel to Australia and Japan and return to North America in 1996.

In their book *Balinese Character* (1942), Bateson and Mead presented a complex psychological portrait of the islanders. Their work was based on the premise that people within a nation, ethnic group, or culture have similar personality configurations, owing to commonalities in their early childhood experiences. This premise, although still held by many people, fell out of favor with professional anthropologists in the 1960s. Systematic studies of individuals showed that in any society, no matter how small, psychological functioning varied greatly and that generalizations of national character did not hold up.

In the end, Bateson and Mead wrote little on their study of the painters of Bali. In 1981, therefore, I went to Batuan to build on their research. Their collection of Batuan art includes paintings and drawings by seventy-one different people. Some made no more than one crude and simple picture. Some were children, copying the work of their elders. But a core group of about twenty-two serious artists made numerous paintings and, over the period of study, exhibited considerable growth in skill and originality of vision. Ten of them were still alive in 1981, so I could talk with them and study the social and cultural contexts in which they had worked.

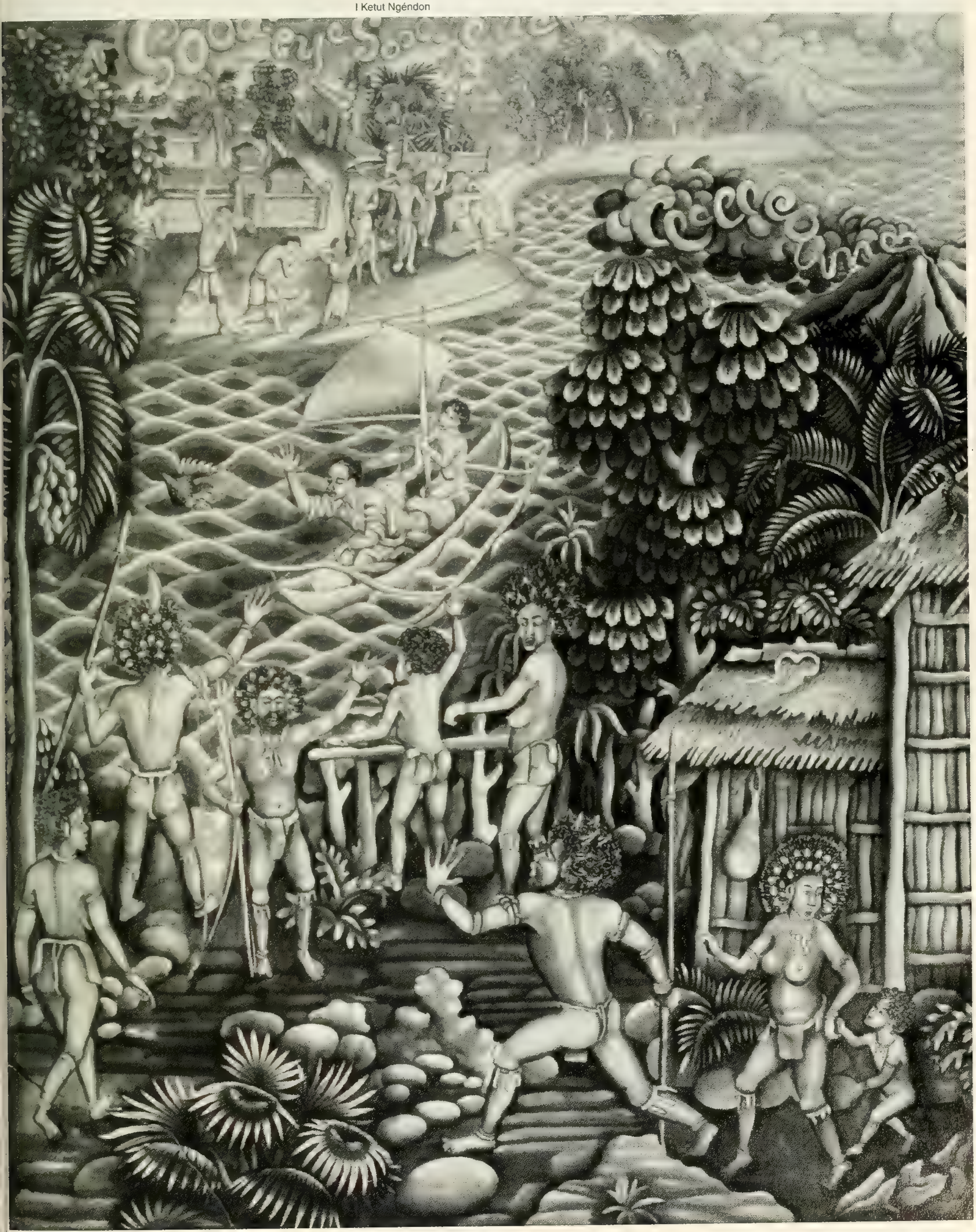
Making drawings with paper, pen, and brush was foreign to the Balinese in the 1930s, for there was little in their traditional art forms that resembled this European genre. Western artists saw a painting as something made to stand alone, sharply cut off from the life around it, hanging on a wall. But most Balinese artworks are elements in rituals, in which musical and dramatic dance performances take precedence. The few Balinese paintings that existed at the time had been made to contribute to ritual activities, primarily as cloth hangings in temples.

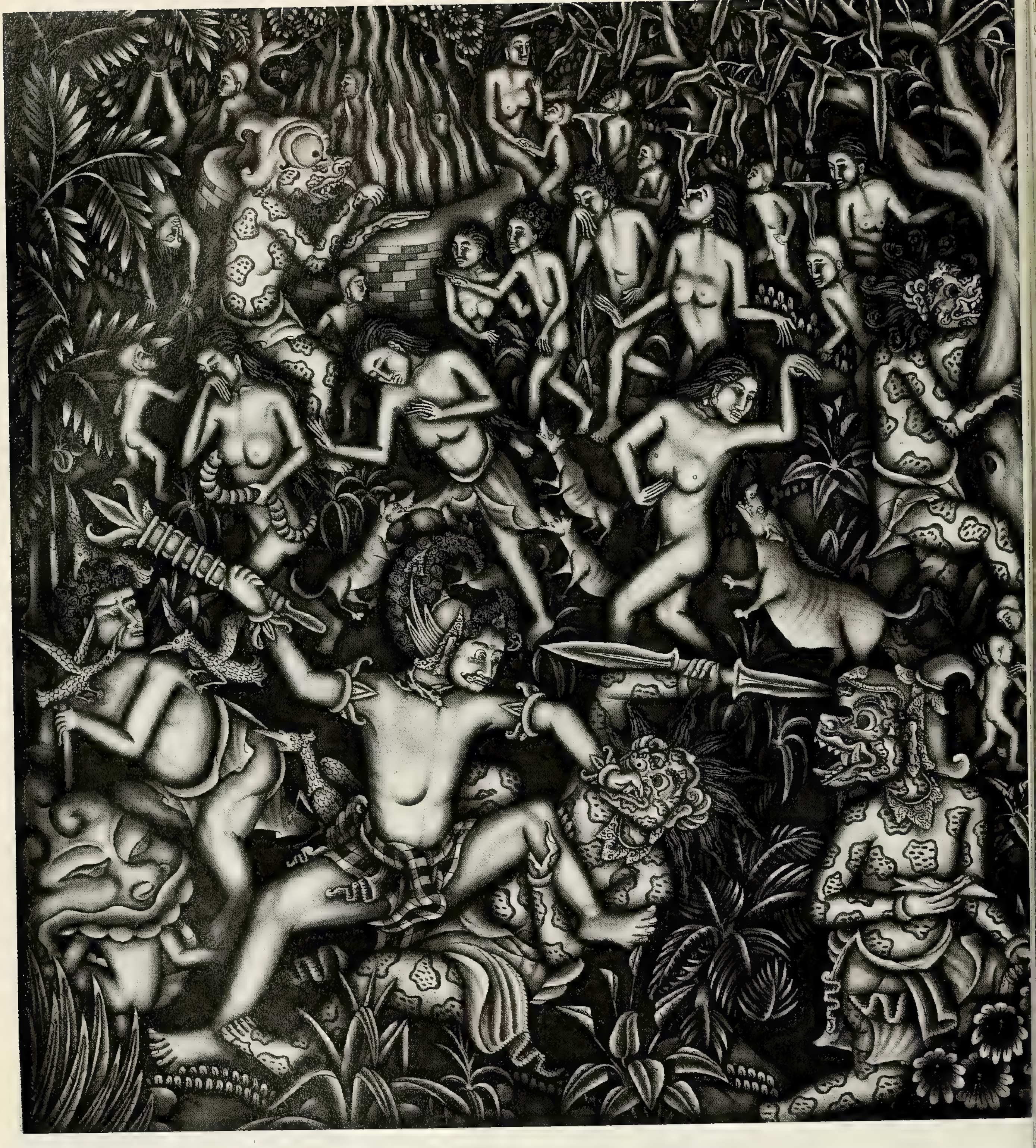
The people of the island call their religion Balinese Hinduism—it is a blend

Adapted from the exhibition catalog, *Images of Power: Balinese Paintings Made for Gregory Bateson and Margaret Mead*, by Hildred Geertz (Honolulu: University of Hawaii Press, 1994). Exhibition organized and circulated by EducArt Projects, Inc., Davis, California. Original paintings in the collection of Lois Bateson; photographed by Philip W. Smith.

Balinese in the background wave goodbye to Gregory Bateson and Margaret Mead, who are shown traveling to a new research site in New Guinea (foreground). The painting was a going-away present for the anthropologists.

I Ketut Ngéndon





Surrounded by tormented souls, the mythic Hindu hero Bima battles the demon guardian of Hell for permission to free his parents' spirits. His mother and father suffer in a caldron of boiling oil (upper left). The father's crime, as a hunter, was to have killed a Brahman priest disguised as a deer.
I Madé Djata

born of Indian Hinduism and indigenous cosmological conceptions, with important influences from Tantric Buddhism and even, indirectly, from Islam and Christianity. In traditional temple hangings that I have studied, stiff figures are painted in a limited range of bright colors—red, blue, and gold—on a white ground. Faces are presented in a standard three-quarter view, and there is no differentiation between foreground and background. Single trees stand between ornately dressed personages, and the white spaces between people and trees are filled in with little teardrop-like motifs representing air. The stories in temple hangings are primarily myths from the heroic age of the *Mahabharata* and the *Ramayana*, Hindu epics from India. Scenes from several different episodes in a story are separated by decorative borders.

Freed from ritual responsibility, the new art did not draw directly on this older style. (Furthermore, there were few examples of traditional Balinese paintings readily available for the novice painters to study because by the 1930s most temple congregations had already replaced their older temple hangings with imported, brightly colored fabrics.) The paintings of the 1930s have agile figures moving about in naturalistic settings. Architectural forms are drawn in three-dimensional perspective, even when the picture is not consistently organized from a single viewpoint.

Most of these drawings are highly detailed and have repeated, rhythmic patterns of leaves and human forms spread over the entire paper. This style mirrors the strong patterning in Balinese textiles and temple wall carvings. I believe it is based on a general Balinese value, what they call *ramé* and I call copiousness. The Balinese word also connotes plenitude, or a busy, crowded sociability, or excitement and fun.

When they used color, the Batuan artists used a palette much wider than the traditional one, but most of their paintings are in black and white. The reliance on black and white may have been suggested by the European artists who encouraged them or may have resulted from their poverty, for they could not afford expensive color paints. The consequent "darkness" of the pictures cannot be traced to traditional Balinese pictures or to some general Balinese value or personality characteristic, since Balinese taste always favors bright colors. Whatever their reasons for developing their dark and moody monochrome style, the Batuan painters found that the works sold, and they continued to develop their art within this mode.

Although the Balinese artists were stimulated by the naturalistic paintings of their European mentors, for the most part they did not choose to depict the externals of Balinese life. Rather, the artists grappled with dangerous, invisible, supernatural beings and powers that, for them, were concealed under the surface of things. Since in Bali one of the main ways of speaking about such matters is through storytelling, many of the pictures were drawn from folktales, shadow puppet shows, and the popular dance-dramas. And many pictures went further, portraying sorcerers, demons, and malevolent spirits. As Bateson and Mead appreciated, the paintings are emotionally charged records of Balinese imaginations.

As personal documents, many of the Batuan paintings reveal a profound concern with disaster and suffering (such as crop failure, illness, theft, and gambling

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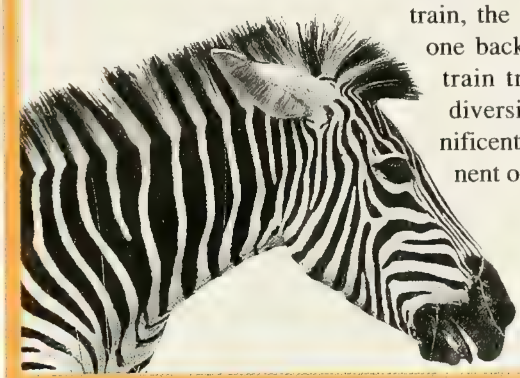

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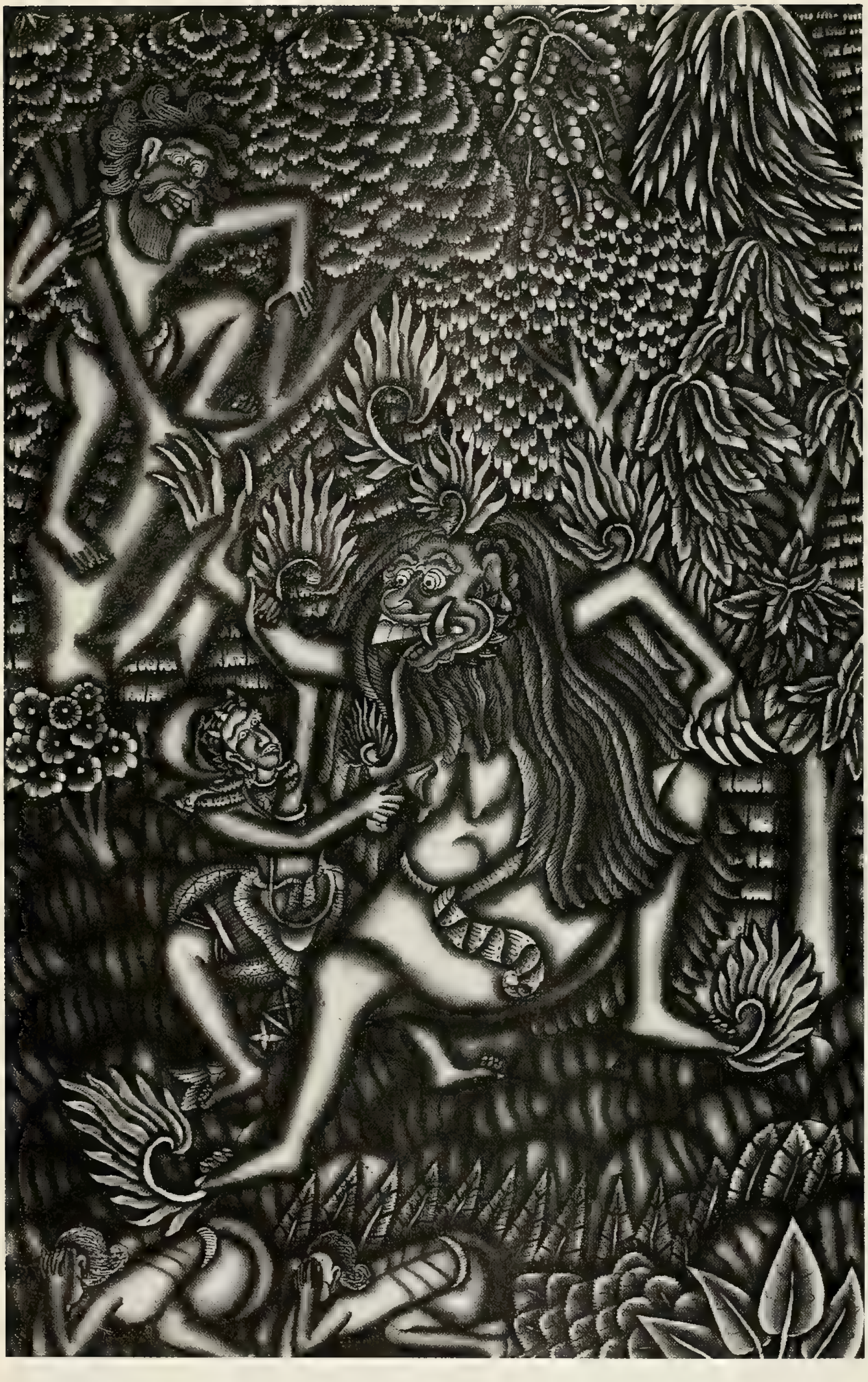


In a scene from a Balinese story, the beautiful and delicate youth Grantang fights with an ogre in order to rescue an abducted princess. Meanwhile the hero's lazy elder brother (upper left) cowers in a tamarind tree.

Ida Bagus Nyoman Sasak

losses). Anyone who has lived in Bali for any length of time knows that the fear of sorcery by fellow villagers and the dread of godly or ancestral wrath governs much of everyday life. These sometimes horrific works vividly portray this pervasive anxiety, normally hidden behind a happy façade of courtesy. The usual idea of Bali as a paradise of contented sensualism or balanced equanimity is given a jarring challenge.

At the same time, the paintings tell about the formidable powers that healers, priests, and kings have for averting or curing such afflictions. They have the capacity to harm, heal, protect, or benefit individuals or communities through a special kind of spiritual power, sometimes referred to by Balinese as *sakti*. These techniques might be called sorcery, but that English term seems too narrow. When Bateson and Mead asked their Balinese assistant, I Madé Kalér, to define *sakti*, he wrote: "The meaning of *sakti* is the ability to prevent anyone from defeating you." He added that this power is hidden in some weak part of the body, such as under the tongue or between the eyebrows, and that if an enemy finds out where the *sakti* is hidden, he can defeat you.

The Batuan pictures portray holy men, priests, kings, warriors, and witches, sometimes in violent conflict with one another. The images portray terror and courage, defeat and victory, war and peace, weakness and strength. Their settings are not merely the magical worlds of stories and myths but also, by implication, the world of everyday life. For the Balinese, this "real" world is pervaded by invisible spirits, both malevolent and benevolent, all in combat with one another and with human beings.

Indeed, the line between story worlds and the real world is never clear in Bali. Actual encounters with demons and sorcerers, miraculous cures, strange deaths, and mysterious visions in the night are the stuff of daily hushed conversations, as are unexpected prosperity and sudden poverty. Any disaster or sudden good fortune immediately becomes food for speculation about its cause. A chronic, wasting lung disease is thought to be the work of mean-hearted neighbors, helped by sorcerers who pretend to be kindly healers. An unusually rich harvest might be explained by the prior discovery of a ring in a rice field, placed there perhaps by a benevolent spirit. A Western notion of "fairy tales" as merely delightful or scary fictions about never-never lands where the impossible can happen would be very strange to most Balinese.

Strong evidence that the themes of these paintings were closely related to fear of other people's malevolent potency appears in an unusual set of illustrations by one of the artists. Bateson and Mead invited Ida Bagus Madé Togog to illustrate his own dreams and to dictate an account of each one. They may have intended to perform a Freudian analysis of his dreams, but they never did so. I have not attempted to search for concealed meanings, but instead have studied their manifest subject matter, which itself reveals much about

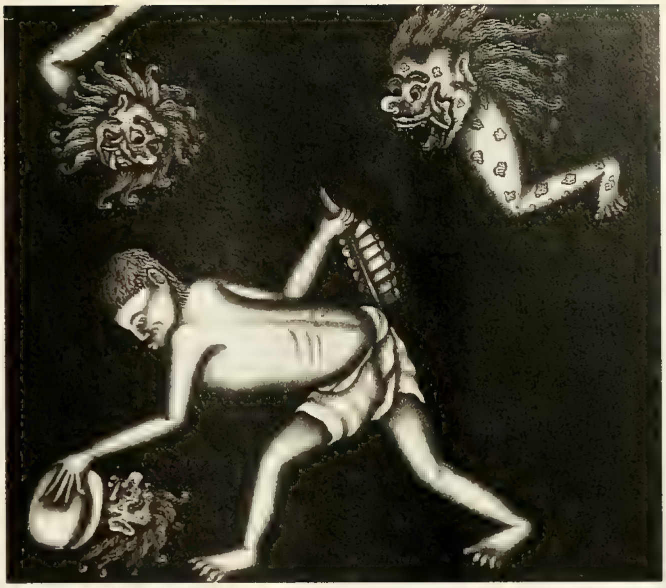
gog's daily life and conscious concerns.
Many of his dreams are about demonic
ings and the dreamer's ability to van-
ish them through his own inner mystical
ength. In at least one case Togog dreamt
receiving spiritual training to become a
rcerer capable of healing or harming
hers. Any Balinese who had such
eams would assume that they were signs
his own increasing mystical compe-
nce. In the 1980s, when I talked with
gog at length about past events in his
e, he sometimes hinted that he had re-
ived the gift of *sakti,* but never said so
plicitly. Although he was not renowned
a master of *sakti,* one of his sons was.

Ironically, these young men who were
ustrating their fantasies about acquiring
e power to harm or help their fellows
ved in a colonial situation in which they
ere essentially powerless. Some of the
les they illustrated are of their former
ngs, who reigned in Bali until this cen-
ry, each one endowed with, or with ac-
ss to, the mystical power of *sakti*. By the
ne the pictures were made, all those for-
er kings were considered to have lost
eir mystical power, as proved by their
efeat by what were considered to be spir-
ually weak foreigners, the Dutch.

But *sakti* is not merely "power" in the
sual Western political sense of the word.
ather, *sakti* is the capacity to join in the
ortal combat of the competing forces of
e universe in order to secure an envelope
safety around oneself and those near
ne. The greatest Balinese kings all had
is mystical potency, but so did many oth-
s, even commoners.

The Batuan pictures, taken against the
ackground of Balinese culture in general,
ave suggested to me that an inner pur-
ose of all Balinese rituals is the mobiliza-
on of *sakti*. Temple ceremonies are car-
ed out largely by local communities and
mily groups, and involve works of
usic, drama, dance, costume making, lit-
rature, painting, and sculpture. They aim
build protective walls and attract spiri-
al guardians against the predations of
ose—humans, as well as nonhumans—
ho can use their magical potency to af-
ict others with dire suffering and death.

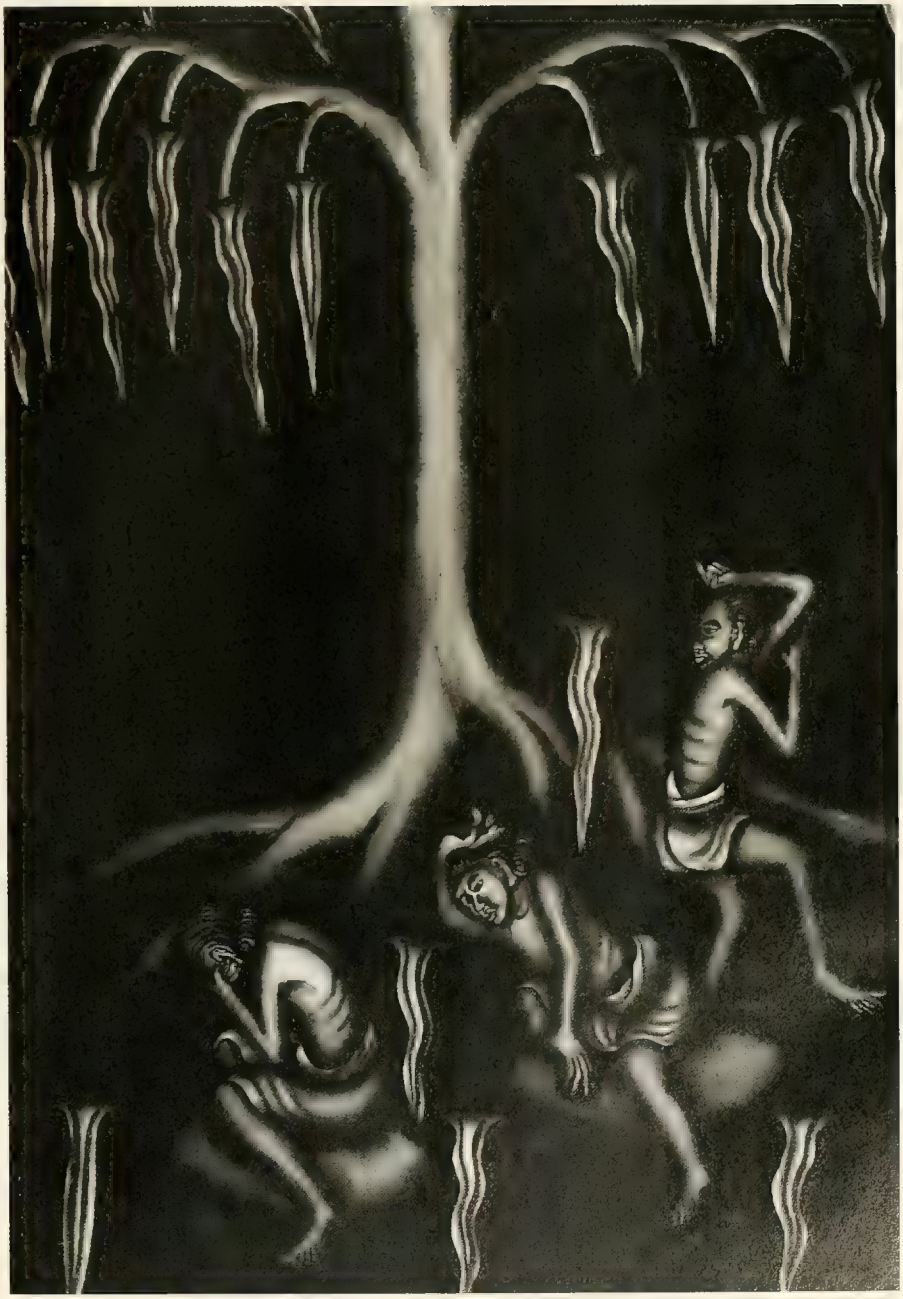
*ildred Geertz, a professor of anthropol-
gy at Princeton University, is curator of
e exhibition "Images of Power" and au-
or of the exhibition catalog. She is cur-
ntly working on a book about the social
istory of Balinese paintings of the 1930s
nd their philosophical and spiritual im-
lications.*



Looking for crickets under a stone at night, left, a boy uncovers a demon. Below: In depicting his dream of a tree with daggers for leaves, the artist included himself (at right).

Ida Bagus Madé Bala

Ida Bagus Madé Togog



Gut Thinking

by Michael S. Gazzaniga

Figuring out how the brain gets its job done isn't easy. I have often thought that if the task of the physicist were placed on the same scale as that of the brain scientist, we would have a better appreciation of the magnitude of the problem facing those trying to bridge the explanatory gap that exists between neural process and behavior. The human brain has something like 12 billion neurons and 10 trillion interconnections called synapses. Figuring out how they all work as independent entities and then how they all interact is supposed to help us understand how we think and feel the way we do. I am not sure the physicist would tackle such a problem.

Nonetheless, legions of scientists are at work on the brain. The Society for Neuroscience, the organization that represents the brain scientists in this country, boasts more than 22,000 members and continues to grow. Their yearly meeting is a regular potpourri of reports and lectures on the function of the brain in everything from the sea slug to the human. Neurons are studied in all these species, as are molecules feeding the neuronal function, as are ion channels in the membranes of the neurons, as are ions themselves. Nerve tracts are followed and compared according to their consistency or variety across species. Lesions are created in animals' brains to see what specific dysfunction might arise. Single-cell recordings are made to gain clues as to how the brain encodes its secrets. Too often, all of this is done by scientists who are not looking beyond their current experiments. They are doing important work that may be helpful for understanding a number of disease processes, but they are not doing it in the context of a larger theoretical framework.

In writing *Descartes' Error: Emotion, Reason, and the Human Brain,* Antonio Damasio has entered the ranks of those who attempt to go beyond their own experimental efforts to try to articulate a broader vision of how the brain works. A hundred years from now, I am sure guardians of scientific ideas will shudder at what all contemporary scientists are offering up as ideas for how the brain works. Worse will be the contempt they will feel for those who don't try to articulate the importance of what they are doing. Damasio, however, is to be congratulated for presenting us with a clear view of how reason and emotions interact to produce our decisions, our beliefs, our plans for action.

Damasio, a distinguished behavioral neurologist and head of the Department of Neurology at the University of Iowa Hospitals and Clinics, has made major contributions to the study of how human patients are changed by naturally occurring brain lesions. He writes that he has always been particularly fascinated with the behavior of patients who have suffered lesions of the orbital or medial prefrontal cortex. While still able to intelligently perform a variety of cognitive tasks, these patients are not able to apply these mental powers to real-world problems. For Damasio, this means that those who argue that "cool" reason is the basis for rational human cognition must be wrong. Somehow, somewhere in the brain, our emotive capacities are integrated with the ability to think, and somehow the union of these two dimensions of mental life yields normal cognition.

DESCARTES' ERROR: EMOTION, REASON, AND THE HUMAN BRAIN, by Antonio R. Damasio; *G. P. Putnam's Sons, 1994; 312 pp., illus.*

Damasio presents his notion in the form of what he calls the "somatic marker hypothesis." In brief, he postulates that when a human is confronted with a problem or a decision, somatic—bodily or visceral—responses help guide the cool products of the rational mind into proper action. As Damasio points out, related ideas have been espoused by a long line of psychologists starting with William James. More recently, psychologist Stanley Schachter, of Columbia University, has also invoked the viscera as being important in generating emotions. Schachter called attention to the fact that patients with severe spinal cord injuries—injuries that prevent certain kinds of sensory information from reaching the brain—found it hard to feel the "heat" of emotion. Over the years, other psychologists, such as Paul Ekman, of the University of California at San Francisco, Carroll Izard, of the University of Delaware, and Robert Zajonc, of Stanford University, have also pointed out the importance of peripheral input in triggering emotional experience.

Damasio rightly observes that in most situations involving real-life decisions, people do not have enough time to think through all the pros and cons in a totally logical way. At some point, most of us go with a feeling. In spite of their cool reasoning capacity, patients with ventral prefrontal lesions do not seem able to access their visceral feelings and, as a result, they stumble around making inappropriate decisions. Damasio argues generally that psychopathic and sociopathic personalities might actually suffer from microanatomical changes to the regions crucial for the integration of emotion and reason. Since such people seem unable to have feelings about right and wrong, good and bad, Damasio suggests they may indeed provide living evidence for his somatic-marker hypothesis.

Of course, the long list of scientists who have been intrigued with the emotional and rational role of the viscera have always faced a conundrum. How do the viscera know which thought to go with, which cognitive process to cue? While most agree that the somatic response is important in emotion, how it works is one of the mysteries of cognitive–emotional interactions. In terms of the emotional ex-

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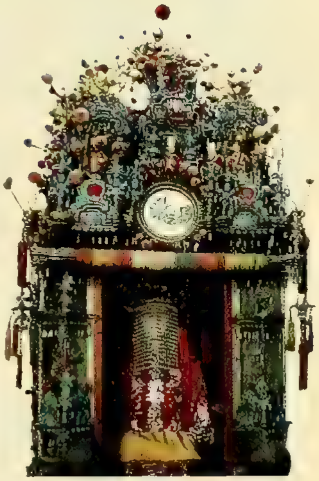

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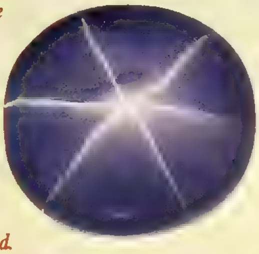

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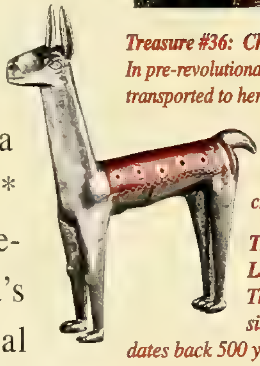

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perience itself, many researchers believe the "felt" emotion is not experienced until it is processed cognitively.

In telling his tale, Damasio offers many views and asides and is never dull. He cautions, for example, against those who think understanding a single neuron will help elucidate the problems of how neural networks interact to produce behavior and cognition. He scorns those who think that by understanding how emotional responses are triggered in the brain, we are somehow lessening the beauty of things like love and poetry. In short, this book gives his reasons for how the body and mind are linked. Descartes' error was to think otherwise—that the mind was somehow not part of the body.

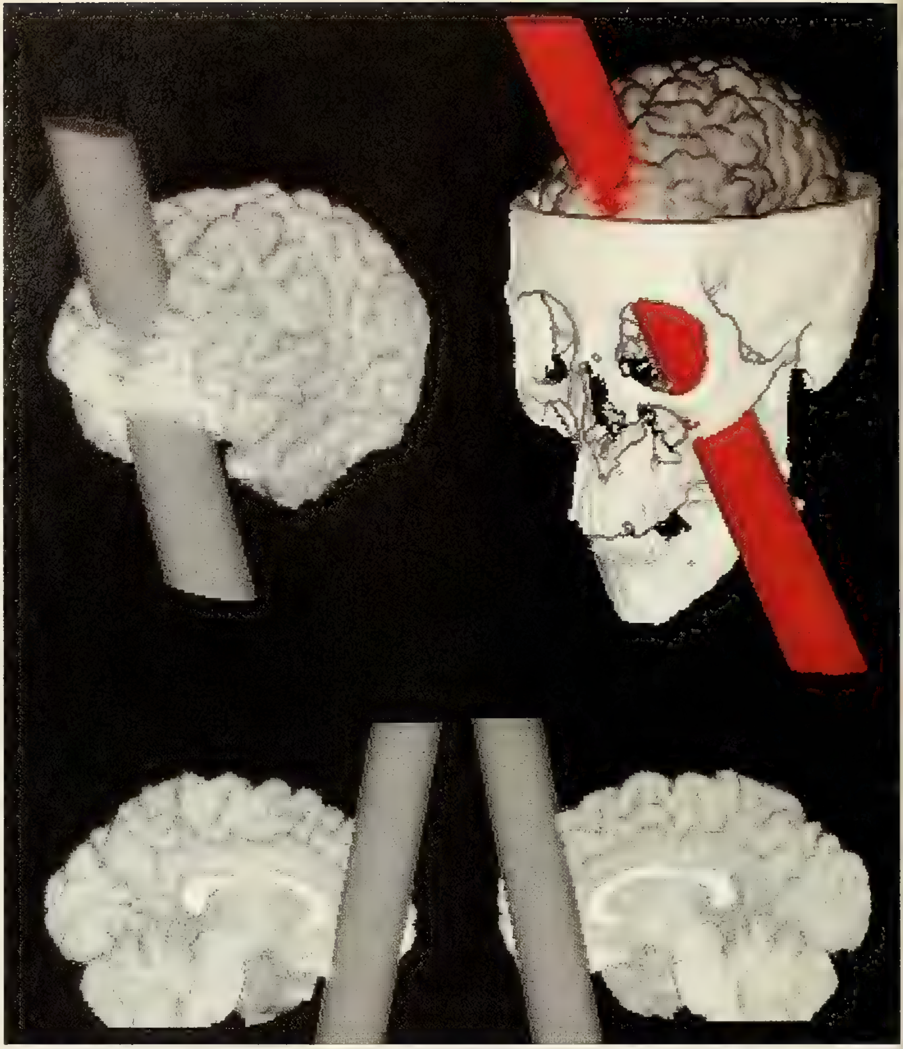
Damasio frequently falls short in linking his ideas to the existing literature on these themes, however. His idea about the relation of time to logical decision making, for example, has been articulated in different terms by scientists in artificial intelligence, who refer to it as the "frame problem." Marvin Minsky, of MIT, has written eloquently about this, as has British philosopher Willard Quine on the whole issue of a priori constraints. In short, these authors have argued that throughout millions of years of evolution, the brain has accumulated devices for focusing and processing information when confronting a new challenge—brain systems do not have time to solve new problems from scratch.

Likewise, the tension that exists between emotion and reason has been extensively studied by economists, who have proposed intricate models that account for the bizarre way humans come to a decision. Some believe it is highly rational; others do not. Finally, Damasio's aside on altruism is offered without reference to major biological theories about the evolution of social behavior. British biologist Richard Dawkins has examined altruism and finds selfish genes creating unselfish individuals in order for genes to survive. Damasio has offered other, more proximate physiological explanations and misses a fundamental insight offered by evolutionary biology.

Although molecular approaches to neuroscience have provided us with vast insight into neuronal function, Damasio is right to observe that molecularly oriented neuroscientists sound more than a little presumptuous in speaking about the mind. On the other hand, all of us studying the brain live in glass houses and are dealing with a very limited theoretical framework for our thinking. No general theory exists as to how the brain works—certainly nothing for the brain is as detailed and elegant as the theory of natural selection. The brain mechanisms involved in memory have been studied for more than a century and represent one of the central issues in neuroscience, but these studies have yielded no agreed-upon suggestion—or even plausible idea—as to how the brain stores and retrieves information. While beautiful science can be done on how single neurons respond to stimulation and may even change their firing threshold as the result of experience, no consensus has been arrived at as to how such cellular mechanisms determine why I remember a phone number.

Nowhere is the paucity of ideas in the field more apparent than when it comes to how the brain enables higher-order functioning such as language, thinking, and feeling. Those of us in the brain business glibly use terms such as "inhibits" or "excites." Dozens upon dozens of neuropsychological models have been put forth on how the frontal lobes serve to inhibit certain kinds of motor and cognitive behavior. Now think about it. The frontal lobes contain billions of neurons with trillions of synaptic connections. Is all of that for inhibiting a motor response? Surely a few neurons could call that shot if necessary. We know untold numbers of events are going on in the frontal lobe at the cellular level. We know that untold numbers of decisions are being made at any given moment. Can brain theory characterize activities by simply claiming they collectively inhibit this or that?

Other definitional problems come up. I recently polled some colleagues, for example, on what they meant when they claimed the brain was plastic. These were



In 1848 the skull of railway worker Phineas Gage was pierced by an iron bar in an accident. Gage recovered physically and retained basic intellect and language functions, but damage to the prefrontal cortex impaired his ability to make appropriate personal decisions and to function socially.

Hanna Damasio; University of Iowa

killed working scientists who have made major contributions to the field. Yet all of hem gave different answers to the queson. When someone remembers somehing, is there a structural—or discrete natomical—change in neuronal synpses? Or is it functional change, which would simply reflect reprogramming of he pattern of neuronal discharges in the ervous system? No one really knows. Ineed, some would argue that a functional hange is a structural change as well. Maybe, maybe not.

And, of course, what constitutes an exlanation? For some, to say information onverges at a particular point in the brain s enough to justify the data as offering an xplanation. Others wonder what happens ext. Some like to say mental disease is aused by neurotransmitter disorders. Others would argue that having a neuroransmitter disorder does not explain why person with schizophrenia might think e is the King of Siam.

The result of this current lack of agreement about basic mechanisms and facts inds those trying to produce coherent theories about the brain hard pressed. The various offerings in recent years have had very little to do with one another. They come off somewhat by necessity as ad hoc, built as they are on each individual's experience with brain research.

Biologists and linguists are far more successful not only in reporting their findngs to the general public but also in presenting a larger context to their scientific endeavors. Stephen Jay Gould's writings, as well as those of Richard Dawkins and Steven Pinker, are notable examples. Their offerings are not ad hoc because hey are able to draw upon one of the great, agreed upon theories of history, the heory of natural selection.

Nonetheless, I remain hopeful that a heory of brain function will someday be generated that will demand the attention of all mind-brain scientists. The very topic is at the core of much of brain and cognitive science and the emergent field of cognitive neuroscience. Great strides are being made in all these areas of research and will continue. Damasio has made a superb contribution to this ongoing and exciting endeavor by recognizing the links between the body and mind, emotion and reason.

Michael S. Gazzaniga is director of the Center for Neuroscience at the University of California, Davis. His most recent book is Nature's Mind.

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The Size and Age of the Universe

by Neil de Grasse Tyson

This past fall, news accounts revealed to the world that the Hubble Space Telescope had measured the age of the universe, which, by the way, turned out to be somewhat less than the age of the oldest stars in our galaxy. While these results may raise an eyebrow or two, they are neither new nor so controversial as you might suppose.

If one camp of astrophysicists were to claim the universe was fifteen thousand years old while another camp claimed it was fifteen billion, we would have a discrepancy of six powers of ten—this would be bad. Fortunately, no such dilemma exists. But in the universe, quantities such as energy, luminosity, size, distance, and time scales span dozens of powers of ten. Knowing this, if two independent measurements fall within only a factor of two or three of each other, we have cause for celebration.

Similar reasoning also applies to ideas. Along the steps of scientific progress, an idea may be correct in concept, yet wrong in detail. Unfortunately, this is not widely appreciated, although it is not for want of trying. (The late Isaac Asimov addressed the subject in one of his more popular essays, "The Relativity of Wrong.") Perhaps the notion conflicts with many of our residual expectations from childhood. If you asked a child to spell "cat" and the result was "kat," the answer would no doubt be marked wrong on an exam, but it is clearly a better approximation of the truth than "xyq." The kat version ought to get at least partial credit.

Most scientific pursuits follow sequences of partial steps, each more closely approximating the ultimate truths of the universe—whatever those truths may be. Nicholas Copernicus, the great Polish astronomer of the fifteenth and sixteenth centuries, is generally credited with restoring the heliocentric (sun-centered) view of the solar system. His model, however, maintained that planets orbit the sun in perfect circles. This detail was wrong, but the basic idea that planets orbit the sun was correct. Subsequent fine-tuning by Tycho Brahe and Johannes Kepler led to a more correct description of the planets in their elliptical orbits. Brahe was a wealthy sixteenth-century Danish astronomer whose private state-of-the-art observatory, built by the king of Denmark, enabled him to measure planetary positions with unprecedented accuracy, and Kepler was a German-born astronomer who derived from Brahe's data the first predictive laws of planetary motion. But even ellipses don't tell the whole story. Today we know that because of the collective gravity of all other objects in the solar system, the path of a planet's orbit around the sun wanders slightly from what Kepler's laws would predict.

Without question, one of the greatest challenges in astrophysics is the attempt to derive reliable distances to objects in the universe. In what is commonly known as the distance "ladder," there exist steps that allow us to estimate distances sequentially from nearby stars to distant galaxies. In the interest of honesty, however, the distance ladder might better be termed the distance "house of cards," because the reliability of each level depends critically on the reliability of the previous, presumably more secure, level.

Among the more secure rungs in the distance ladder are Cepheid variable stars. (The Cepheids are rare, very luminous red giant stars—with ten thousand times the luminosity of the sun—whose inward gravitational pressures and outward thermal and radiative pressures have temporarily fallen out of balance. They are named after Cepheus, the constellation in which the first variable star of this variety, delta Cephei, was discovered.) Recently, the Hubble Space Telescope discovered and monitored Cepheid variables in the spiral galaxy M100, which lies near the center of a cluster of thousands of galaxies, spread over twelve degrees of the sky in the direction of the constellation Virgo. This Virgo cluster is the nearest of its size to our Local Group of galaxies, but it is far enough away to give ground-based observations an extraordinarily challenging, if not impossible, time measuring individual stars among its members. The distance to Virgo is a crucial step because the distances to many clusters that are much farther away have been estimated with methods that invoke the distance to the Virgo cluster itself as a yardstick.

The Holy Grail at the top of the distance ladder is the Hubble constant, a measure of the universe's rate of expansion. (The astrophysics community has wisely insured that among the projects competing for the time slots on the space telescope, observations that lead to an estimate of the Hubble constant will be given priority.) Edwin Hubble started it all in 1929 when he made the seminal discovery that the recession velocity of a galaxy is proportional to its distance, with a constant of proportionality *K*. The *K* became known as the Hubble constant, for which *H* became the standard symbol. Also in honor of Hubble, the orbiting space telescope was named the Hubble Space Telescope, thus maintaining the tradition of naming astronomical spacecraft after famous dead astronomers. For a measured recession velocity of a galaxy, the Hubble constant prescribes the distance from the Milky Way.

The inverse of the Hubble constant provides a measure of the age of the universe by mathematically "turning back the clock." For example, if a car is 110 miles away (the distance), and you time it to be moving away at a law-abiding fifty-five miles per hour (the recession velocity), then simple division will estimate for you how long ago the car was in the spot where

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you are standing. While in the car, you would normally read the speedometer to learn your speed. But the highway patrol officer hiding in the bushes has ways to learn your speed without the benefit of a peek at your dashboard. Police use a Doppler radar gun, which computes your car's speed in the same manner that astrophysicists compute the speed of galaxies. The car's speed is derived from the wavelength shift in the return signal just as a galaxy's speed is derived from the wavelength shift of its emitted light.

For nearly all galaxies in the observable universe, the recession velocity is found to be proportional to distance. What does this look like? Nearby galaxies recede slowly and distant galaxies recede quickly, which is the precise signature of an explosion: the exploded parts from hand grenades, bombs, and even fireworks all behave in the same way. For this reason, it is no accident that the term "big bang" has been adopted to describe the scene at the origin of the universe. When you perform arithmetic that is no different from what was applied to our law-abiding car (you just need to know the Hubble constant), you can estimate the time in the past when the entire universe was in the same place—the beginning. A high Hubble constant implies a smaller, younger universe, while a low Hubble constant implies a larger, older universe.

For no special reason, distances to stars, galaxies, quasars, and the horizon of the universe are all reckoned in parsecs. A parsec (3.26 light-years) is the distance a star would be if you were to observe its location shifting against the background stars by an angle of one arc second as Earth orbits from one side of the sun to the other. Nearby stars exhibit large shifts while distant stars exhibit correspondingly shorter shifts against the background sky. As a phenomenon, it is no different from the shift you see when you hold your finger at arm's length while looking at it with one eye and then the other. The finger appears to shift from side to side.

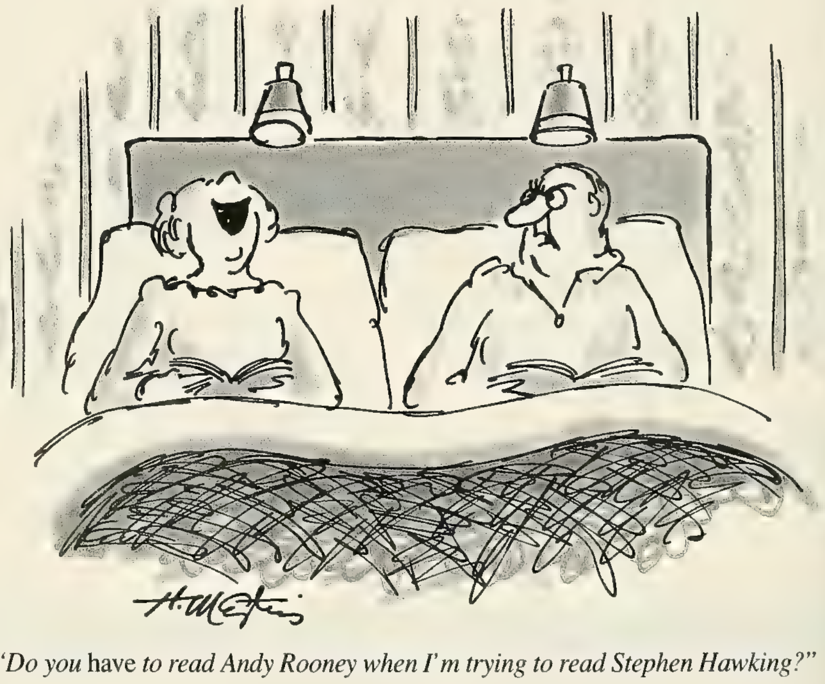
For handy reference, the nearest star system to the sun, alpha Centauri, is about 1.3 parsecs away. The nearest galaxy that resembles our own spiral Milky Way, the Andromeda galaxy, is about 700 kiloparsecs away. The nearest quasar, 3C273, is about 600 megaparsecs away. The edge of the observable universe, the horizon beyond which information cannot reach us, is about four gigaparsecs away. The prefix kilo is shorthand for one thousand; mega, for one million; and giga, for one billion.

Except for some early, extremely high estimates, including that of Edwin Hubble himself (based on a mix-up in the Cepheid luminosity scale), the measured value of the Hubble constant has consistently fallen between 40 and 100 kilometers per second per megaparsec, with contemporary values accumulating between 65 and 85. The range translates directly into our uncertainty of the universe's size and age. Aside from being a number that one might chat about at a cocktail party, the actual size of the universe is relatively unimportant. The real curiosity is its age, which impacts heavily on our understanding of galaxy formation and star formation. If the universe is "too young," then we do not know how galaxies were produced in the short times available during the early epochs of the universe. Even worse than exposing this ignorance is discovering that well-tested theories of stellar evolution indicate ages for some star clusters in our own Milky Way that are somewhat older than the universe itself—a decidedly unpleasant situation.

Because of their high and predictable luminosity, Cepheid variable stars make useful "standard candles" for estimating the Hubble constant and the age of the universe. Standard candles, when they are found, are cherished in astrophysics for they are our only reliable yardsticks. On time scales that range from days to months, the outer gaseous layers of the Cepheids expand and contract while the stars themselves increase and decrease in luminosity. Fortuitously, the period of a Cepheid's light variation is tightly correlated with its average luminosity. In the early twentieth century, a Harvard astronomer, Henrietta S. Leavitt, first noted this behavior among twenty-five Cepheids in the Small Magellanic Cloud, a nearby dwarf galaxy. To the delight of astrophysicists, the period (which is easy to measure) allows you to derive the luminosity. The luminosity, when combined with the measured brightness (which is also easy to measure), gives you a reliable distance to the star through a simple formula. If you are one of those who tracks the rich and famous, note that within the list of Cepheid celebrities we find Polaris, the North Star.

Rising hopefuls in the category of standard candles are supernovae, which shine at typically millions of times the luminosity of Cepheids, and are thus visible over much greater distances. At the moment, there is some hope that their peak luminosity is constant from one exploding star to the next, which would crown supernovae as the best available standard candles in the universe and thus secure an unimpeachable rung on the distance ladder. Unfortunately, to be effective they first must be discovered, which depends on how diligently the sky is searched and monitored because you never know when, and you never know where, the next supernova will explode.

To derive an accurate age of the universe also requires knowledge of the cosmic mass density, a disturbingly uncertain number even by astronomical standards. Taken together, the mass density and the



"Do you have *to read Andy Rooney when I'm trying to read Stephen Hawking?"*

ubble tell us whether the universe will
‹pand forever in the "big chill" or col-
ıpse one day in the "big squeeze." There
no doubt that these are profound num-
ers. Our understanding of the fate of the
niverse rests upon them. We should
ıerefore not be surprised that tremendous
ıedia attention is given to every new
ıeasurement of the Hubble constant.

Using space telescope measurements of
ıe Cepheids in the Virgo cluster, Wendy
reedman, of the Carnegie Observatories,
nd collaborators calculated a Hubble
onstant of 80 ± 17 kilometers per second
er megaparsec. One can safely proclaim
ıat this is the most secure measurement
f the Hubble constant ever obtained. The
alue, however, with its honest interval of
ıncertainty, falls comfortably within
cores of previous (although less certain)
round-based measurements.

The estimated mass density of the uni-
erse ranges from a small fraction of the
ritical amount needed to ultimately arrest
he cosmic expansion (as inferred from
bservations) to the critical density itself
as wished for by many theorists). Across
his range, a Hubble constant of 80 pro-
ides for a universe that is anywhere from
ıbout 12 billion down to 8 billion years
ld. For some people, this is cause for dis-
ress because the latest estimate for the age
f the oldest stars in the Milky Way is
ıbout 14 billion years. I can still hear it,
'How can stars in the universe be older
han the universe itself?" Well, they
shouldn't be. To confirm or refute the re-
ent measurements, we must continue to
lerive the Hubble constant for many more
galaxies in the Virgo cluster, and for
galaxies that are much farther away. We
must also "push the envelope" of stellar
evolution models to see whether younger
stellar ages (10 to 12 billion rather than 14
billion years) are possible for the oldest
stars. Maybe not tomorrow or next week,
but one day there will emerge a closer approximation of the truths of the universe.

For now, I do not wallow in despair. I marvel at the agreement among very different estimates. Because behind the debates, the controversies, and the headline hyperbole, I rejoice in having some idea of the size and age of the universe—even if it is just to within a factor of two.

Neil de Grasse Tyson is an astrophysicist with a joint appointment at the Hayden Planetarium and Princeton University. His recent book Universe Down to Earth *is available from Columbia University Press.*

CELESTIAL EVENTS

by Joe Rao

If you've ever wondered which astronomical object has been photographed the most, you may be surprised to learn that it is not the sun or the moon, but rather Mars. From 1905 through 1964, E. C. Slipher, of the Lowell Observatory in Flagstaff, Arizona, took almost 200,000 photographs of this intriguing planet. In 1956 alone (a year when Mars made a particularly close approach to Earth), Slipher took 37,000 photographs. The best times to photograph the planet are during oppositions, when Earth and Mars line up on the same side of the sun, and near their closest approach to one another.

Martian oppositions occur roughly every twenty-six months, and one is coming up on February 11, when the planet shines at a magnitude of –1.2, and when we will be almost 63 million miles from it, about as far away as we can be during such an alignment. Nevertheless, Mars will be almost as bright as Sirius, the brightest star in the night sky. The last really favorable opposition (they tend to repeat at intervals of fifteen or seventeen years) was in September 1988, when the red planet was about 36 million miles away. The reason that all Mars oppositions are not equal is that the planet has a highly elliptical orbit, and the best oppositions occur when Mars is closest to the sun.

This month, Mars rises in the east–northeast at sunset and takes all night to cross the southern sky. It will be high in the south at midnight and will appear as a bright yellowish orange "star" to the right of the sickle-shaped pattern of stars that outlines the mane and chest of Leo, the Lion. A good telescope will show the white north polar icecap and a few dark surface areas, such as Syrtis Major, an extensive plateau near the Martian equator.

The next favorable opposition will occur in August 2003. So, as you admire Mars these frosty cold February nights, try to imagine yourself gazing at it on some warm late-summer evening eight years hence, when it will appear to shine more than four times as brightly as it does now.

THE PLANETS IN FEBRUARY

Mercury pulls out of the sun's glare and should be visible by the 12th. On that date, it will lie some twenty-seven degrees to the east (lower left) of Venus, but this distance is nearly halved by the 28th. Mercury will be shining eight moon diameters below and to the right of the thin crescent moon on the 27th.

Venus shines brilliantly in the dawn, although not quite as brightly as last month, and it sinks about five degrees closer to the horizon. For the rest of the year, Venus seen through a telescope will look like a very small, featureless gibbous moon. On the morning of the 26th, you'll see a beautiful crescent moon above and to the right of Venus, and if you're using a good telescope, you'll find Venus lying less than a degree north of the bluish 8th-magnitude planet Neptune, currently the farthest planet (until 1999) from the sun.

Mars reaches opposition on the 11th and provides a striking sight to the right (west) of the sickle of Leo. Thirteen hours before it arrives at opposition, it will reach its closest point to Earth in 1995. The time of opposition and closest approach do not coincide because at the time of opposition, the paths of the two planets are not parallel but are converging slightly.

Jupiter, well to the left (west) of Venus, appears as another brilliant morning "star," and rises three to five hours before sunrise. By dawn it is in the south nearly at the meridian. The bright reddish star Antares is about six degrees below and to the right of Jupiter. The moon, just past last quarter, will be visible just to the east of Jupiter as they rise on the morning of the 23d.

Saturn, shining like a first-magnitude star, is low in the western sky and sets about two hours after sundown on the 1st. Look for it on this night far to the left (east) of a skinny sliver of the moon. By midmonth, Saturn is swallowed up by the sun's glare.

The **Moon** is at first quarter at 7:54 A.M., EST, on the 7th; full moon is on the 15th at 7:15 A.M., EST, and last-quarter moon is on the 22d at 8:04 A.M. There is no new moon this month, the first time that such a circumstance has occurred in February since 1957. Compensating for this lack were two new moons in January; there will be two more in March.

Joe Rao is a meteorologist and a guest lecturer at the American Museum–Hayden Planetarium.

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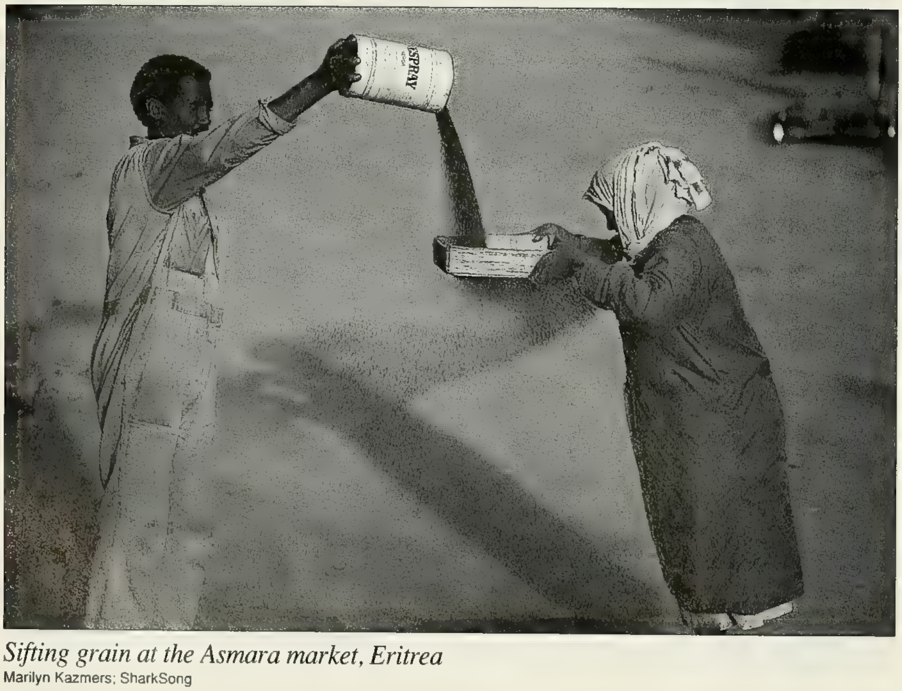

Sifting grain at the Asmara market, Eritrea

Marilyn Kazmers; SharkSong

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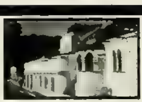
in the bottom of a remote Mexican canyon



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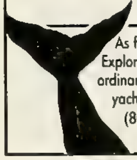

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"Images of Power," an exhibition of 103 Balinese paintings collected by Margaret Mead and Gregory Bateson in the 1930s, will be displayed in Gallery 77 from Friday, February 3, until Wednesday, May 3. While they were living and working in the village of Batuan, Mead and Bateson collected more than 1,200 paintings and sketches depicting myths, burial rites, and all aspects of village life. The exhibition's curator, Hildred Geertz, a professor of anthropology at Princeton University, will describe how Balinese peasant artists learned their techniques. She will also explore how Mead and Bateson persuaded the painters to allow their works to be collected and will describe her own association with these artists fifty years later. Her talk will take place on Thursday, February 2, at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for tickets and information.

BLACK HISTORY MONTH

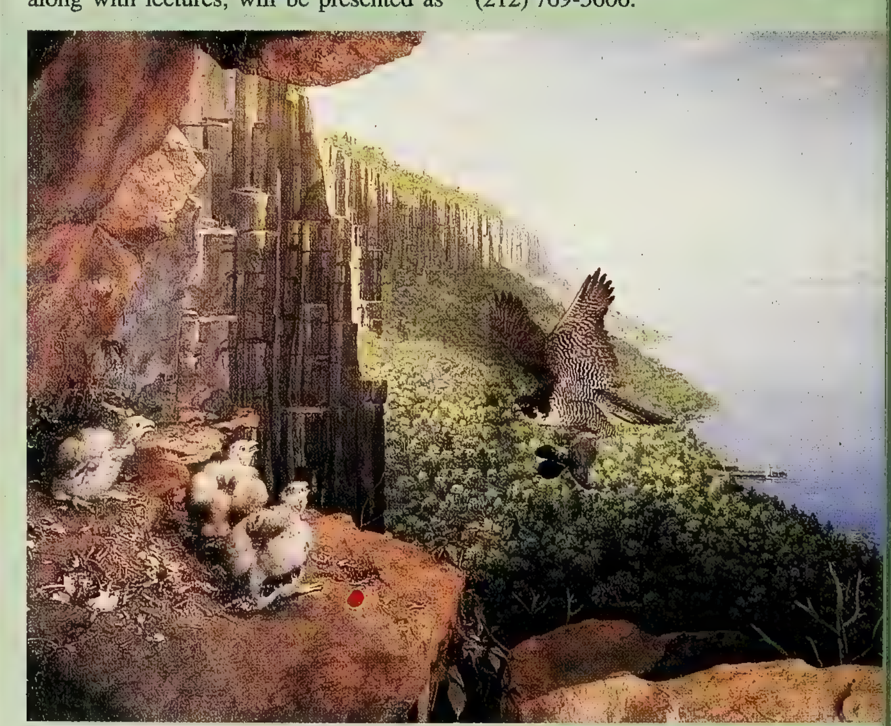
In February, the Museum will be celebrating Black History Month. Demonstrations of African, African American, and Afro-Caribbean music, dance, and theater, along with lectures, will be presented as part of the Education Department's year-long series "Unity Through Diversity." For a brochure and further information call (212) 769-5315.

THE SHOESTRING PLAYERS

The Shoestring Players, an ensemble o eight actors and a percussionist, will present four international folktales on Saturday, February 25, for children between five and ten years of age. Two performances will be given in the Kaufmann Theater, at 1:30 and 3:30 P.M. Call (212) 769-5606 for ticket availability.

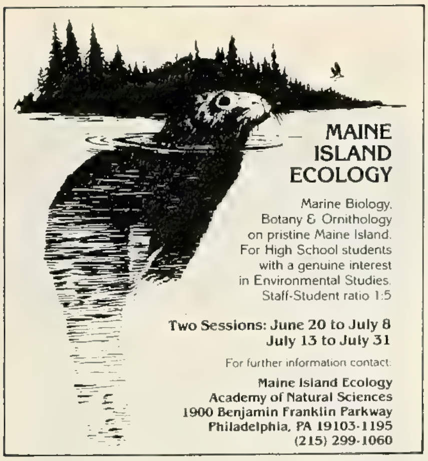
JEWISH CEMETERIES AND SYNAGOGUES IN POLAND

Until World War II, more than 3.5 million Jews lived in Poland. On Thursday February 23, Samuel Gruber, director of the Jewish Heritage Council of the World Monuments Fund will talk about aspects of their culture that have survived. A number of historic Jewish sites in Poland have been protected and preserved, including the restored Tempel Synagogue in Kraków. Gruber's slide-illustrated talk will be given at 7:00 P.M. in the Kaufmann Theater. For information and tickets, call (212) 769-5606.



The Museum's habitat group of nesting peregrine falcons was created nearly ninety years ago by ornithologist Frank M. Chapman, who made the institution's bird collection one of the finest in the world. Chapman was the first to base dioramas on actual sites, like this one on the bluffs of the Palisades along New York's Hudson River. The display is one of fifty featured in the Museum's 125th-anniversary "Expedition" tours.

AMNH; Beckett/Chesek



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HAT'S OUT THERE IN THE UNIVERSE?

A new Sky Show, "The 10 Most Asked uestions About the Universe," opens 'ednesday, February 8. Among the ques- ons posed will be: What is a black hole? there life elsewhere in the universe? oes Planet X exist?

On Tuesday, February 21, at 7:30 P.M., enneth Mighell, an associate research ientist at Columbia University, will talk bout the formation and evolution of warf galaxies. This slide-illustrated lec- ire is part of the "Frontiers in Astronomy nd Astrophysics" series. Tickets are $8 6 for members). Call (212) 769-5900 for formation about all Planetarium events, cluding the current exhibition, "The Jniverse Revealed: Recent Images from he Hubble Space Telescope."

ROM PROJECTILE POINTS TO
TOM BOMBS

On Thursday, February 16, Archeolo- ist Daniel J. Lenihan, chief of the Na- ional Park Service's Submerged Cultural Resources Unit, will talk about his under- water explorations at Pearl Harbor. In ad- lition to describing his research, which in- ludes mapping the U.S.S. *Arizona* and ighteen other ships sunk in the surprise apanese attack, Lenihan will discuss the ships that were sunk at Bikini during the atom bomb tests of 1946 and his exploration of shipwrecks in the Great Lakes. His talk will take place at 7:00 P.M. in the Kaufmann Theater. For ticket availability, call (212) 769-5606.

WHALES OF TETHYS

Three hundred million years after vertebrates first colonized land, some mammals returned to Tethys, a sea that stretched between what are now Spain and Indonesia. Philip Gingerich, professor of geological sciences and director of the Museum of Paleontology at the University of Michigan, will talk about the evolution of whales, based on his cetacean fossil finds in areas once inundated by Tethys. His slide-illustrated lecture will be presented on Thursday, February 9, at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for information and tickets.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

American Museum of Natural History

NATURE AND CIVILIZATION IN THE MEDITERRANEAN

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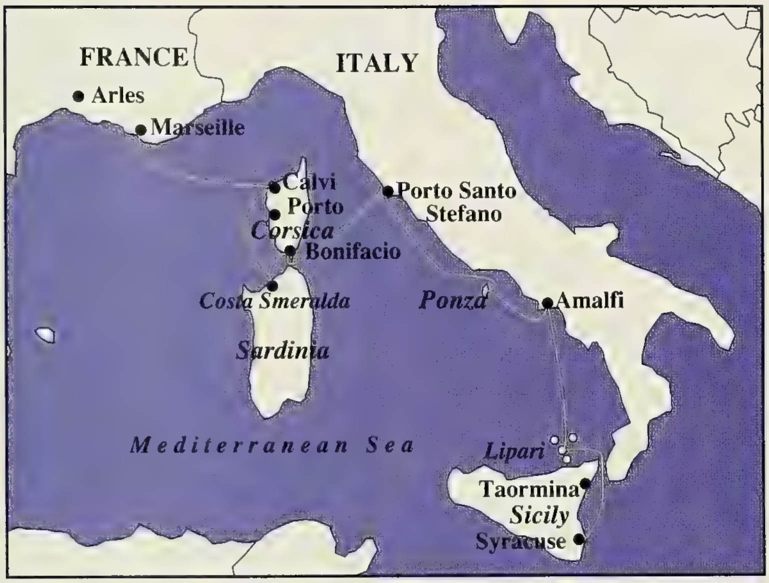
July 17-31, 1995



The Mediterranean is a melting pot of cultures and traditions from the greatest seafaring civilizations of the West. But tremendous geologic processes have also helped to shape the Mediterranean and its history. The American Museum of Natural History has designed a special Mediterranean cruise focusing on the relationship between nature and civilization. We will visit islands created by tremendous volcanic eruptions that evolved into lush, fertile places where human populations could thrive, as well as places where such eruptions buried whole cities under layers of ash and pumice. In addition to the magnificent cliffs, volcanoes and spectacular coastlines in this region, we will explore excavated cities, Roman ruins and medieval towns. Join us aboard *Le Ponant*, a 32-cabin French yacht, as we explore the western Mediterranean.

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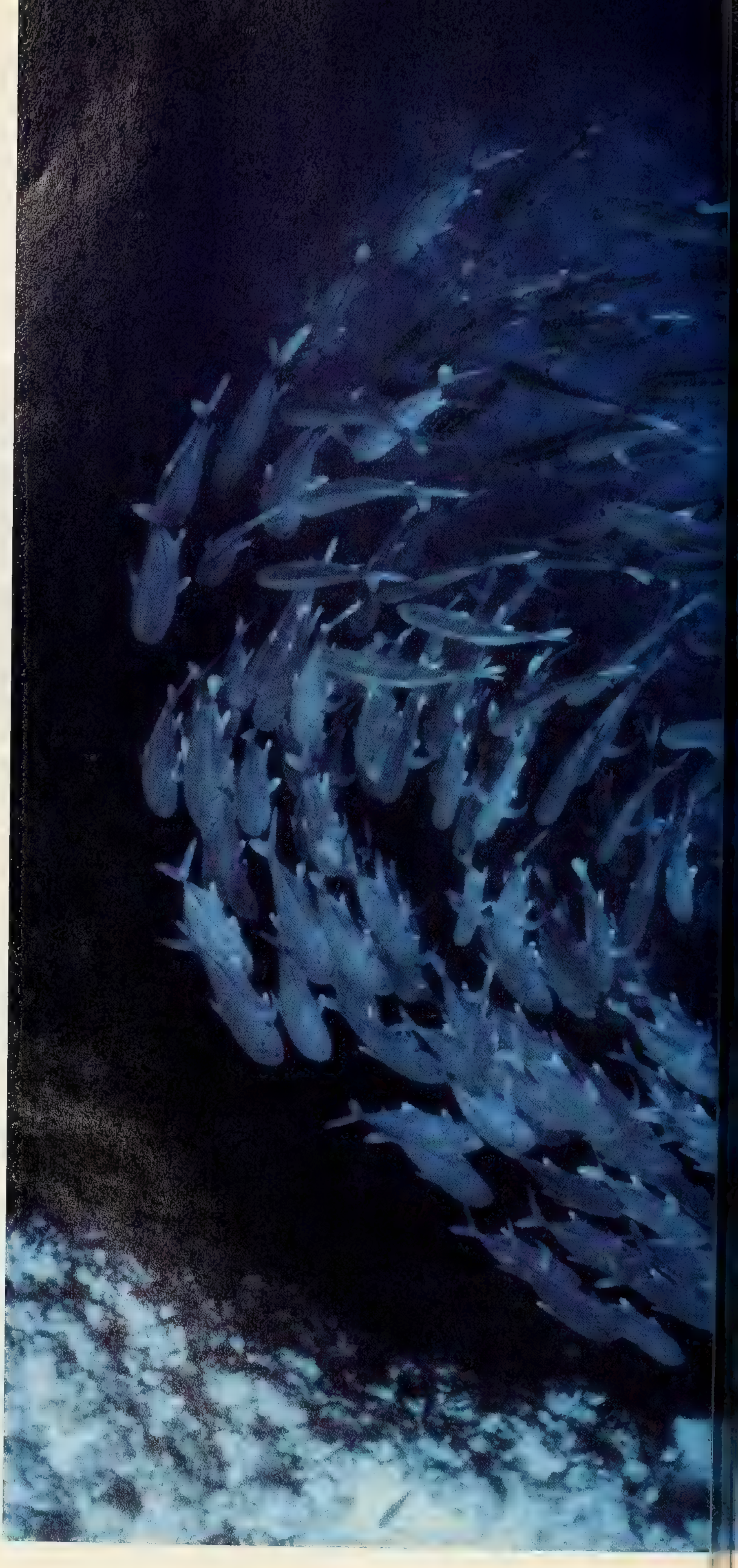
School Days

Just off the sandy ledges ringing Sipadan Island, near Borneo, undersea cliffs plunge some 2,000 feet into the depths. Against this deep-blue background, a school of bigeye trevally, an Indo-Pacific species of jack, forms a moving circle some thirty feet below the surface. Sleek, streamlined, and a foot or two long, jacks are predators. At dawn and dusk, and perhaps on the brightest moonlit nights, they hunt down schools of small, herringlike fish. By day, jacks tend to school in a leisurely fashion and can themselves become prey. Should a barracuda or shark approach a loose-knit school, the jacks cue into the movements of their neighbors and instantly fall into circular formation. Amid the swirling silver, a predator has a hard time zeroing in on a single tail or fin. Watching the school over several days, photographer–marine biologist Norbert Wu had a rare opportunity to witness an attack: "A large barracuda had been hovering near the edges of this school, waiting to pick off a straggler. It darted in, but was chased off by a wall of angry jacks, nipping and biting. Only then did I notice the many scars and wounds on the barracuda, proof of its previous attempts to prey on individual jacks, and proof of the school's ability to defend itself."—*J. R.*

Photograph by Norbert Wu



AUTHORS

As a child, **Peter J. Marchand** (page 26) spent much of his time in the woods of Massachusetts, an experience to which he attributes his lifelong fascination with nature. High-elevation forests held particular interest for him and eventually led to his doctoral studies of timberline in the Northeast and to investigations of climate and timberline in the mountains of interior Alaska. For a few years afterward, he strayed into alpine tundra habitats, studying plant adaptations to disturbance, but he eventually came back to the subalpine forests of the northern Appalachians and the collaborative research effort he reports on in his article. Marchand now lives in a high-desert forest—the pinyon-juniper woodlands of northern Arizona. For more on the inner workings of New England forests, readers might want to take a look at Marchand's book *North Woods* (Boston: Appalachian Mountain Club Books, 1987).

"When people ask me what I play, I tell them the tape recorder," **Donald R. Hill** (page 34) says by way of explaining his musical ability. As an undergraduate at Pomona College in the late fifties, he sometimes spent less time in the classroom than on the road recording country music, blues, and jazz. After a year in Korea as an Army linguist, Hill went on to earn degrees in anthropology and folklore from San Francisco State and Indiana Universities. Since 1978, he has been a professor of anthropology and Africana and Latino studies at the State University of New York College at Oneonta. Earlier, he did a three-year stint in the Education Department of the American Museum of Natural History, running its minority curatorial training program. "About twenty-five graduated before it folded, and many went on to become important in the museum world," he says proudly. When Hill isn't teaching, he dips into his collection of seventeen thousand 78-RPM records and works on such projects as making a CD of early steel band music and editing his great-grandmother's diaries. Hill's 1994 book, *Calypso Calaloo: Early Carnival Music in Trinidad*, was published by University Press of Florida. Other books on pan are Stephen Stuempfle's *The Steelband Movement: Local Creativity and National Identity in Trinidad and Tobago* (Philadelphia: University of Pennsylvania Press, *in press*) and George "Sonny" Goddard's *Forty Years in the Steelbands: 1939–1979* (London: Karia Press, 1991).

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Robert Heinsohn (page 44) was out valking in the countryside near Canberra ne day, when a chance encounter with a roup of black birds with red eyes hanged his life. "They started their ving-waving, eye-bulging trick," he ecalls, "and I was hooked." His ascination with white-winged choughs ventually led Heinsohn to earn a loctorate from the Australian National Jniversity and begin a career in volutionary ecology. Supported by a ostdoctoral fellowship from the University of Minnesota, Heinsohn neaded to Africa, where he studied young lions in Tanzania's Serengeti National Park. After three years there, he returned to Australia, where he works on the conservation biology of the endangered glossy-black cockatoo and encourages his students at the National University to study choughs. Heinsohn is not the only naturalist in his family; his father is a zoologist, as is his Scottish wife, Sarah, whom he met when they were both observing lions in Africa. She now studies kookaburras in Australia. For more information on choughs and the social behavior of animals, Heinsohn recommends Ian Rowley's *Bird Life* (Sydney: Collins, 1974) and Robert Trivers's *Social Evolution* (London: Benjamin Cummings, 1985).

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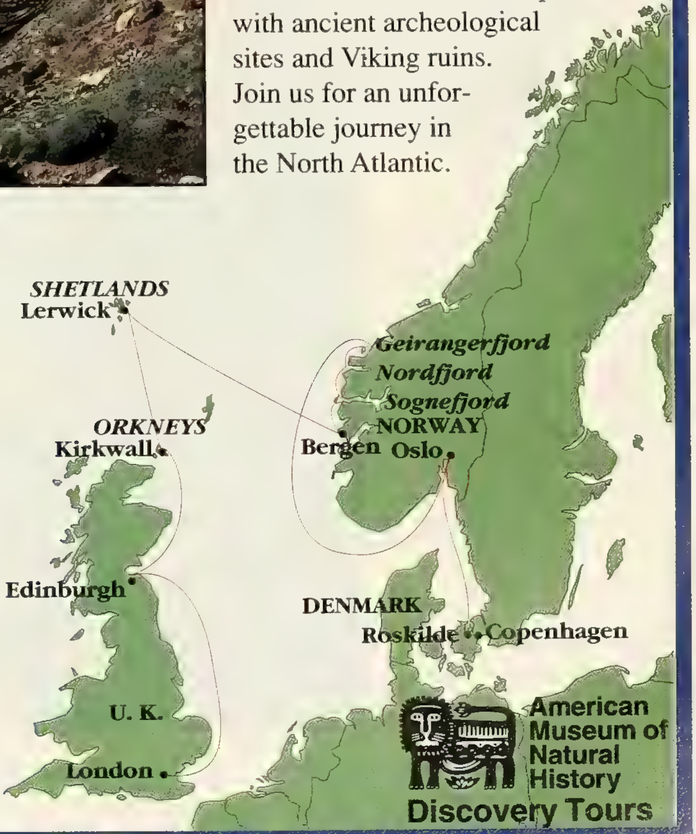
The Vikings, Scandinavia's master shipbuilders who plundered and settled coastal Europe and the British Isles from the 9th to the 11th centuries, also crossed the North Atlantic to Iceland, Greenland and North America. Raiding cities, towns and remote villages, they left their mark peoples and places throughout western Europe and the North Atlantic.

Sailing in their wake along a well-traveled Viking route, a team of lecturers from the American Museum will lead a cruise this summer aboard the deluxe *Silver Wind* from Scandinavia to the British Isles. Our route will take us to the spectacular fjords of Norway, coastal cities and towns founded and raided by the Norsemen and remote islands replete with ancient archeological sites and Viking ruins. Join us for an unforgettable journey in the North Atlantic.



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A native of New York City, **Raymond M. Russo** (page 52) rests atop a ridge in New Zealand's Southern Alps, one of many tectonically active areas he has explored. While an undergraduate at Brown University, he was drawn into geophysics by the school's strong planetary science department. He went on to earn his M.S. and Ph.D. in geophysics from Northwestern University. His dissertation, which he finished in 1990, focused on the tectonics of the Caribbean, particularly along the coasts of Venezuela and Trinidad. Russo is currently finishing a postdoctoral fellowship at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. He will soon be moving to the coast of southern France where, at the Laboratoire de Tectonophysiques in Montpellier, he will do further research on how seismic waves travel through various minerals. Russo began his studies of the mantle flow beneath the Andes with **Paul G. Silver,** who first suggested that they take on the South American project. Silver, who was born in seismically active Los Angeles, is shown standing next to a solar-powered seismic station, one of many he and his colleagues have set up in the Bolivian Andes. Silver first earned a B.S. in psychology, then did a six-year stint as a jazz drummer in San Francisco before going on to earn a B.A. in geology. He is now a senior staff scientist at the Carnegie Institution's terrestrial magnetism department, where he has worked since earning his Ph.D. from the Scripps Institution of Oceanography at the University of California, San Diego, in 1982. At a recent meeting of the American Geophysics Union in San Francisco, Russo and Silver presented evidence that the mantle flow is forced to go around ocean crust subducted along trenches skirting eastern Australia—a situation similar to what they found along the Pacific coast of South America. For a more technical account of how they mapped the mantle flow, read their article in *Science* (February 25, 1994).

While photographing the schooling jacks that appear in this month's "Natural Moment," **Norbert Wu** (page 80) says he "became entranced by the endless wanderings of this school of fish and spent hours between dives swimming over, under, and around the school, trying to capture the sense of motion on film." He took this underwater shot while swimming over a 2,000-foot drop-off just off Sipadan Island, twenty miles off the coast of Borneo. Using Kodachrome 64 film in available light, he captured the swirl of fish with a Nikonos V camera and UW-Nikkor 15 mm lens. Wu is the president of Mo Yung Productions, a stock photography library of both underwater and topside images. Currently, he is specializing in rain forest wildlife and is a producer and consultant to multimedia educational programs. Wu's latest book is *Splendors of the Sea* (Southport: Hugh Lauter Levin Associates, 1994). This large-format publication contains 260 color photographs and a text that encompasses marine environments, natural history, and Wu's experiences with marine life, "ranging from giant sperm whales to tiny gobies."

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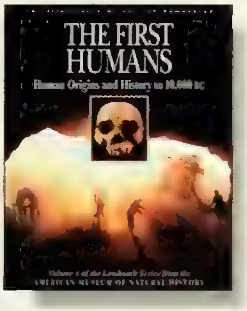
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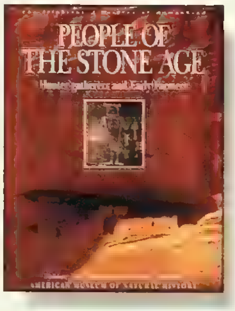
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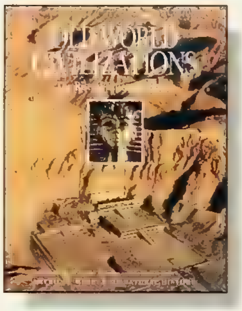
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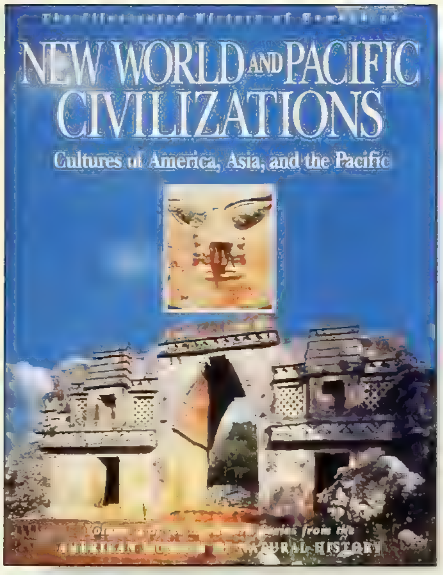
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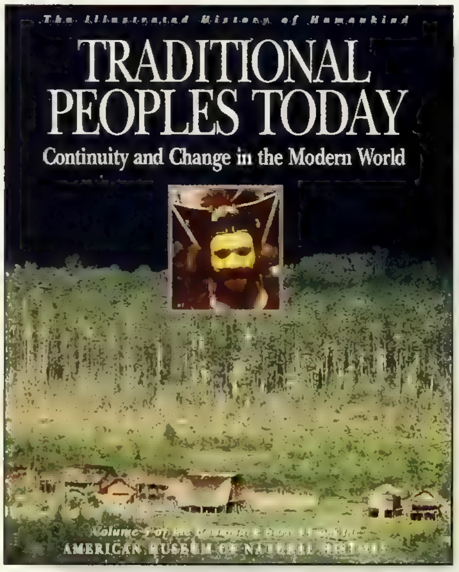
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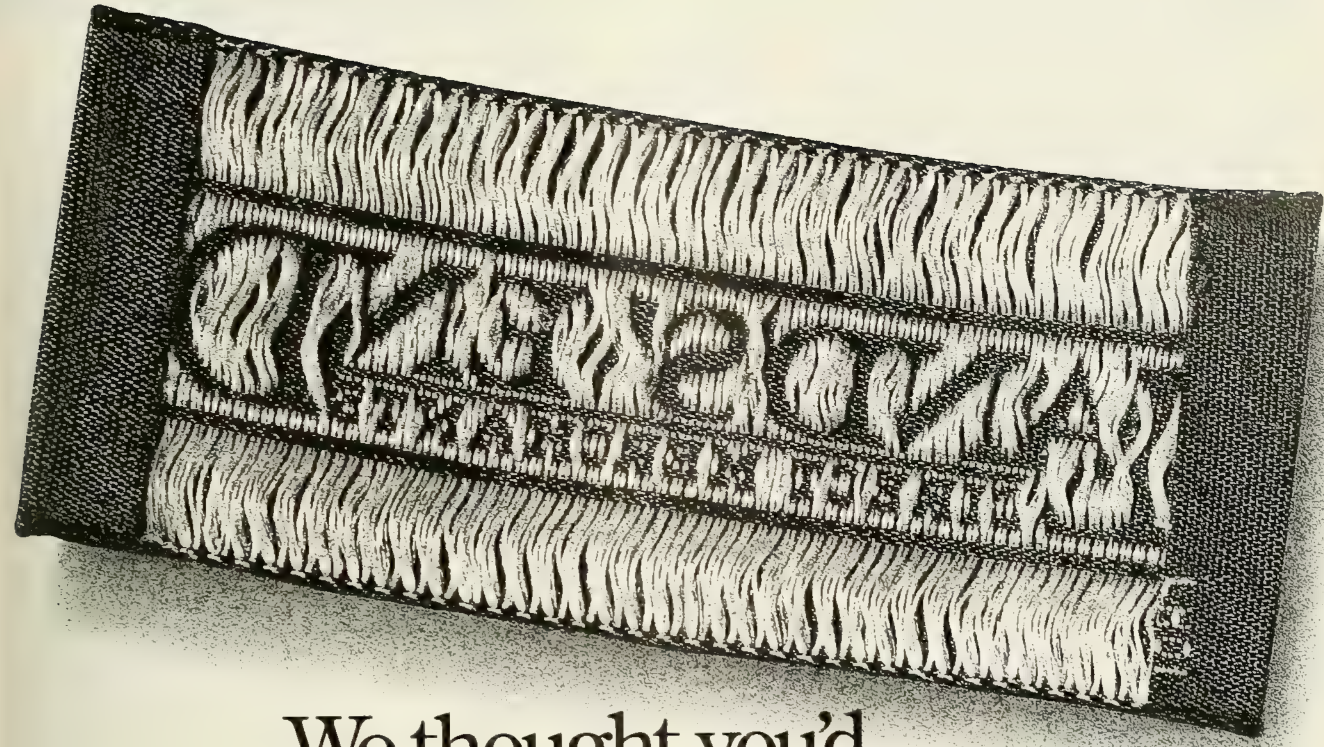

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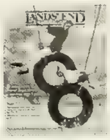

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HORNETS OR YELLOW JACKETS?

The nest shown in "Hidden Assets" ("The Natural Moment," December 1994) appears to be typical of hornets and certainly not, as stated, of yellow jackets. Both hornets and yellow jackets build nests of paper, which they form and process from natural materials; hornets, however, almost invariably build their nests in trees or attached to some object above the ground, while yellow jackets construct their nests in cavities. In winter, a hornet nest in a deciduous tree is conspicuous and easily seen and attacked by birds and other foragers.

Also, yellow jackets are relatively small, about one-quarter the size of hornets. The insect shown in the beak of the nutcracker in the photograph is much too large to be a yellow jacket.

Of course, the terms "hornet" and "yellow jacket" are common names and may have different connotations in different places.

ALEXANDER J. SULZER
Bowden, Georgia

THE EDITORS REPLY: The common perception that yellow jackets nest only in cavities or in the ground, while hornets build nests above ground, was expressed by a swarm of readers who questioned the accuracy of our December "Natural Moment" text.

The U. S. Department of Agriculture's handbook *The Yellowjackets of North America North of Mexico* notes that although in the United States the term "hornet" is commonly applied to two large species (*Dolichovespula maculata* and *Vespa crabro*) in the subfamily of yellow jackets "and sometimes to all aerial-nesting yellowjackets," only species in the genus *Vespa* (of which *V. crabro* is the only North American example) are hornets. James Carpenter, of the American Museum's Department of Entomology, adds that *V. crabro*, an introduced hornet species, does not build free-hanging nests but nests in hollow logs and tree cavities.

Thus, while in popular parlance the wasp pictured in December's "Natural Moment" could be termed a hornet, it is indeed a yellow jacket.

CORN SMUT, NORTH AMERICAN STYLE

I found the article "Why I Will Continue To Eat Corn Smut" (January 1995) of great interest, especially because the Hopi people (whose reservation is near Homolovi Ruins, which they consider a sacred site) also value corn smut.

In her book *Hopi Cookery,* Juanita Tiger Kavena writes of fried nanha (a corn smut recipe) that "older Hopis considered it a real delicacy but few younger Hopis have eaten it. The children do play with [corn smut] out in the corn fields, however, by chasing one another and smearing it on those who get caught."

KAREN BERGGREN
Homolovi Ruins State Park
Winslow, Arizona

Michael Quintor

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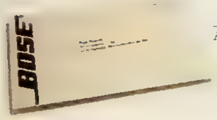


Predator Versus Predator

In the Yukon, when the going gets tough, the tough get eaten

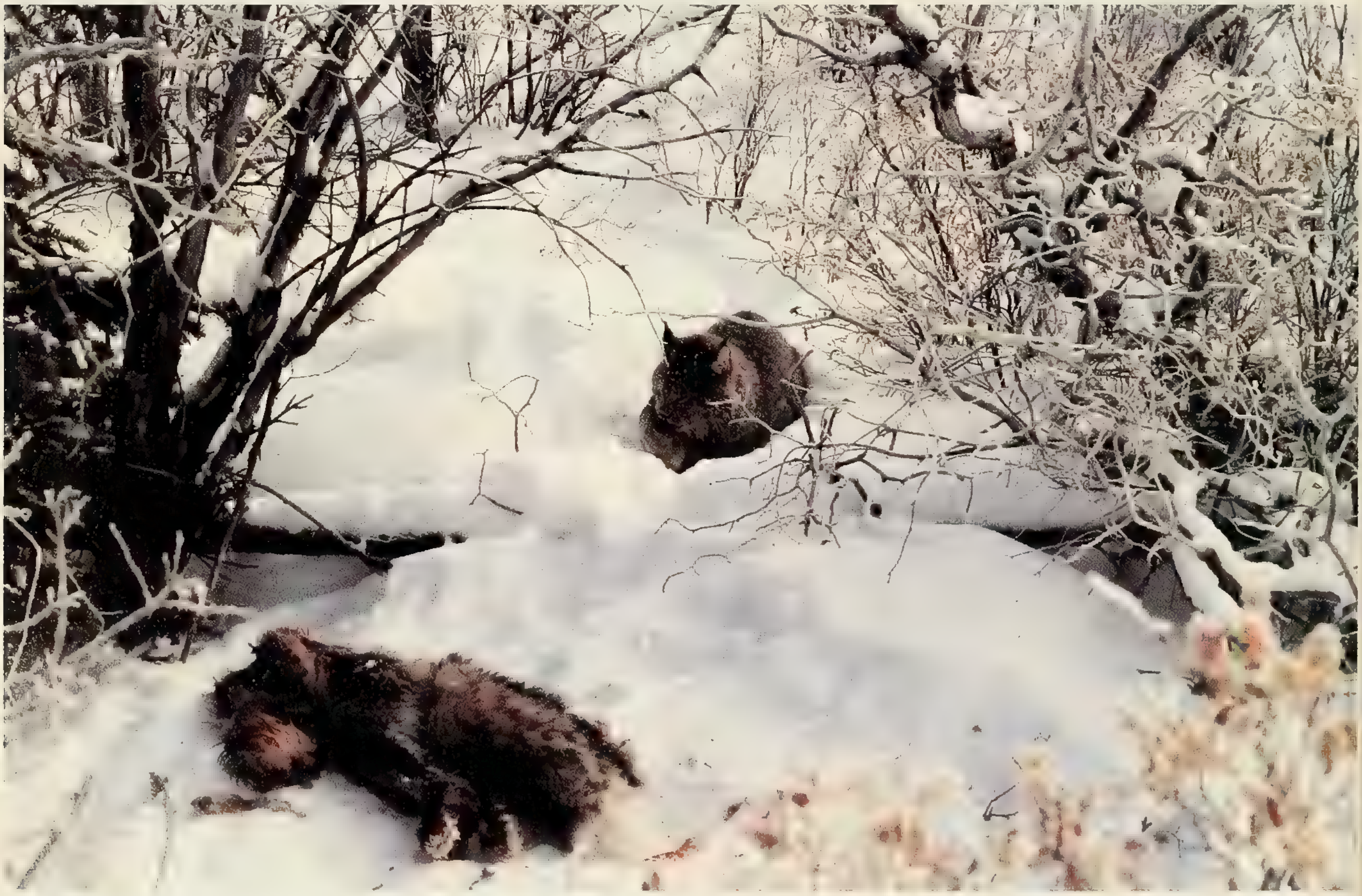
by Mark O'Donoghue, Elizabeth Hofer, and Frank I. Doyle

As the coyote trotted across the gravel road in front of us, we slowed our car to admire its tawny coat and graceful gait. We frequently observed coyotes as we went about our work, since they are fond of using roadways to expedite their travel and hunt voles. But something was different this time. Instead of the coyote's usual cautious attention to human intruders and their vehicles, this animal kept its gaze intently fixed straight ahead.

Halfway across the road, the coyote abruptly broke into a full-bore charge that ended in two long bounds and a flurry of fur and flying paws. We slammed on the brakes and backed up the car. The coyote ran off into the forest, leaving behind the body of a dead lynx. Careful examination revealed that the coyote had broken the neck of its victim, a young animal weighing only about fifteen pounds. Even so, the lynx was at least two-thirds the size of the coyote and quite capable of putting up a good fight. Was this incident a fluke or an example of a regular, although seldom observed, predatory behavior?

For the past eight years, we have worked in the southwest Yukon Territory as a part of the Kluane Boreal Forest Ecosystem Project, a collaborative research effort by biologists from three Canadian universities. The broad aim of these studies is to gain an understanding about how the food web in the extensive coniferous forests of the north works, that is, what determines how many predators and how many herbivores there are and of what species.

The studies have focused on one of the



A lynx rests by the remains of a red fox it has killed and been feeding on.
Susan Antpoehler

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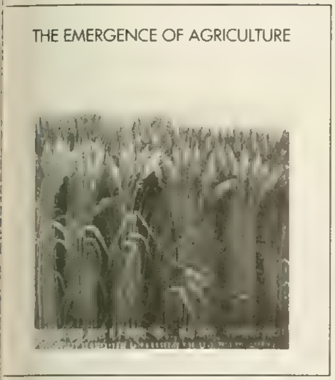
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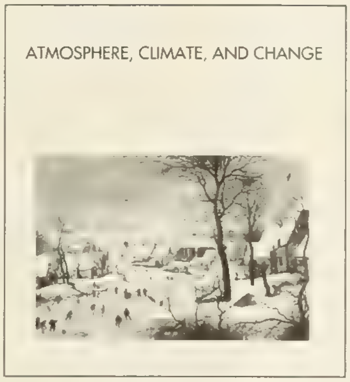
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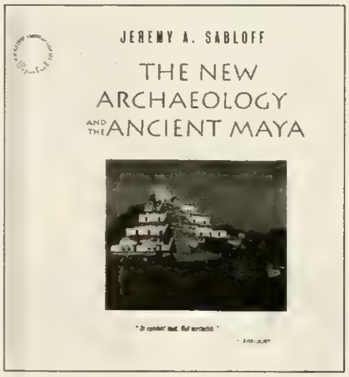
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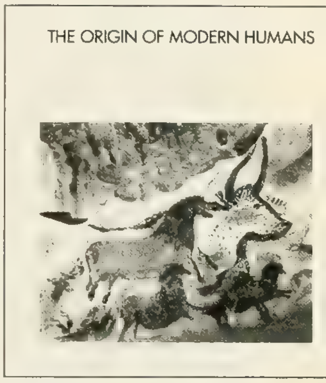
THE ORIGIN OF MODERN HUMANS

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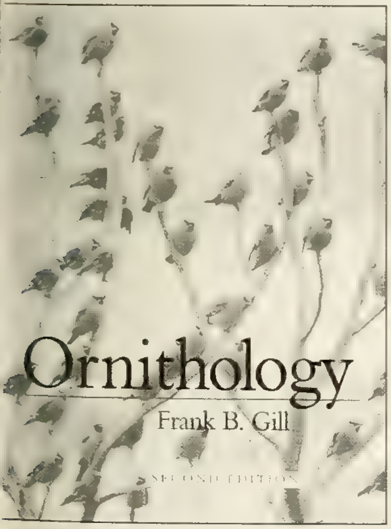
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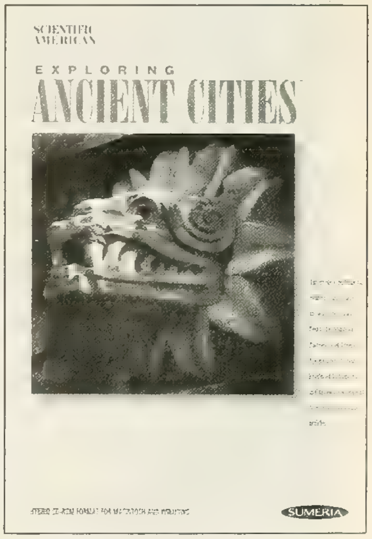
SCIENTIFIC AMERICAN
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SUMERIA

W.H. FREEMAN AND COMPANY PUBLISHERS, 41 Madison Avenue, New York, N.Y. 10010 most conspicuous features of northern ecology, the ten-year population cycle of the snowshoe hare, a cycle that we were to learn can drastically affect the interactions among the hare's predators. Along with red squirrels and voles, snowshoe hares are the most abundant plant-eating mammals in the boreal forests of Canada and Alaska. They are also the staple food of many predatory mammals and birds, including lynxes, coyotes, great horned owls, and goshawks. Throughout this region, the number of hares fluctuates drastically over time, with populations reaching peak densities every eight to eleven years. These high points are followed by crashes in which hare numbers may decline to one three-hundredths of their highest levels. We know from fur company records that this cycle has been going on for as long as records have been kept, but there is still no widely accepted explanation for why it happens. Both predator–prey and plant–herbivore interactions have been proposed as the principal mechanisms generating the cycle, and part of the research objective of the Kluane Project is to untangle these hypotheses.

Whatever the cause of the boom-and-bust snowshoe hare cycle, it has an unmistakable impact on the hare's predators. In a study in central Alberta that spanned three cyclic peaks from 1961 to 1982, Lloyd Keith, of the University of Wisconsin, and his colleagues documented that as hare numbers rose and fell, so did populations of lynxes, coyotes, great horned owls, and goshawks. These ups and downs in predator numbers (well known to trappers, native peoples, and other residents of the north) are a focus of our own research with the Kluane Project. We have been concentrating on a 135-square-mile study area in a broad, forested valley, keeping track of radio-collared lynxes and coyotes and following fresh tracks in the snow. We also follow radio-tagged owls, hawks, and other birds of prey year-round and monitor nests in the summer.

Snowshoe hare populations at Kluane peaked at about 450 animals per square mile in 1989 and 1990 and then declined rapidly during the next two winters. In the spring of 1992, there were only about seventy hares per square mile. The lynx population also plummeted during this period, going from an estimated sixty to fifteen. Did these animals leave our area or die, and if they died, what killed them?

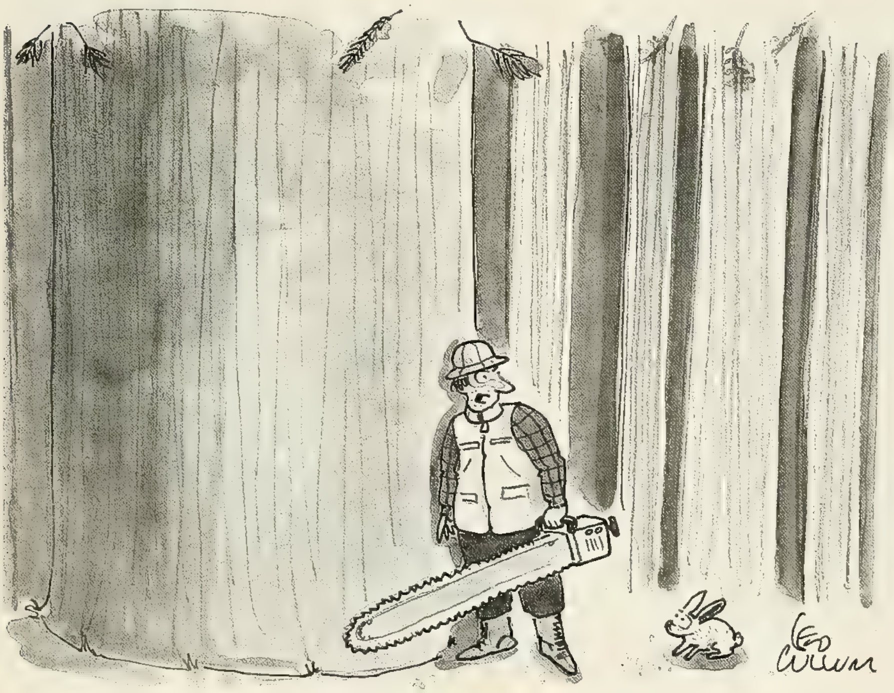
Our radio collars gave us a clue as to what was happening. At the beginning of the winter of 1991–92—when hare numbers were still fairly high—we started monitoring the radio signals of fifteen of the fifty lynxes we estimated were in the area. By spring, seven of them were still alive, two had died, and another six had disappeared from our study area. We learned the fate of several of these missing animals later, when collars were returned to us by trappers in Alaska, British Columbia, and the Northwest Territories. The longest of these migrations, most likely undertaken in search of better hunting grounds or mating opportunities, was more than 500 miles as the crow flies.

The next winter, hare numbers were at their lowest. We began the 1992–93 season monitoring nine lynxes; by April, none were alive in our study area. And this time, the lynxes were not migrating; they were dying close to home.

The first to go, in late November, was an old friend—an adult male first captured in 1982, making it at least eleven years old and a survivor of one full hare cycle. This animal—still in good condition and eating well (the remains of three red squirrels were found in its stomach)—had been killed by a wolf. We were surprised by this unusual predation; incidents of predators preying on lynxes have not been widely reported in the scientific literature, and we assumed many of our animals would simply starve when hare numbers dropped. However, the unusual was soon to prove a pattern in this difficult winter of harsh weather and scarce food.

December and January were very cold and stormy months. Temperatures dipped to –50° F on several occasions, and there were week-long stretches of frigid temperatures, stiff north winds, and blowing snow. The deaths of two lynxes during this two-month period testified to the harsh conditions. We found the mostly consumed remains and radio collar of a female under a mound of snow. Fresh blood, a second set of lynx tracks, and the way the carcass was cached under the snow told us that our female had fallen prey to one of her own kind. A post-mortem examination of the color and consistency of the marrow in her leg bones revealed that this female had been malnourished. Another lynx, a young male, left his home range in late January but never made it far. He died from starvation five days later, about five miles northwest of his usual haunts.

Few lynxes were in good enough condition to make the long-distance moves we had observed the previous winter. Two of our radio-collared animals—a male and a female—left their established home ranges and moved up several miles into the alpine area of the surrounding mountains. This took them out of the dense thickets of spruce forest, where—in a good year—hares are abundant, and into the treeless ridges of willow scrub. We speculate that in a last ditch effort to find food, these lynxes had moved up the mountains in search of ptarmigan.



"Relax! I'm going to plant another one."

"Say something dirty into his radio collar."

Neither animal was successful. We found the scattered remains of the female about three weeks after she left her home range. Fresh blood, a chewed-up collar, and tracks provided strong evidence that she had been killed by a wolverine. A couple of weeks later, we found the chewed collar and some fur and blood from the male, with wolf and wolverine tracks nearby.

Two other studies of lynxes in northern Canada have also concluded that when times are rough, predators sometimes feed on their fellow carnivores. Brian Slough, of the Yukon's Department of Renewable Resources, confirmed two cases of lynxes killing other lynxes, and one of a wolverine killing a lynx during the winter of 1992–93, when snowshoe hares were in decline. Kim Poole, of the Department of Renewable Resources in the Northwest Territories, found an instance of one lynx killing another during the same period. Both of these researchers also found other dead lynxes that had been scavenged and perhaps killed by other predators. Trappers' observations and native oral tradition support the notion that cannibalism and predation among predators often occurs when hares are scarce.

Lynxes are not always the victims in predator–predator encounters. In December 1992, while following the trail of a lynx, one of our trackers came upon the partly eaten carcass of a red fox. Tracks in the snow showed that the lynx had surprised the fox coming over a knoll and taken fourteen long bounds before catching its prey. In neighboring Alaska, biologists described thirteen cases of lynxes preying on red foxes; Brian Slough reported two such cases in the Yukon.

Over the past eight years, we have also documented forty-five cases of raptors killing other birds of prey. Goshawks, for example, are year-round residents of the boreal forest. These large forest hawks feed heavily on hares when they are plentiful. The number of nesting pairs of goshawks in our study area, a mirror of population changes, declined from eight in 1990 to one in 1992. Lloyd Keith found a similar pattern for goshawks in Alberta.

Raptor censuses south of the boreal zone suggest that some of the goshawks may have flown south as hare numbers dropped. We know from following radio-tagged birds, however, that many elect to stay put, which is a risky choice in winters when hares are scarce. Since 1990, we have found the remains of eight adult goshawks in our study area. We have not always been certain why these birds died, but in four instances, we have good evidence that they were killed by other raptors. In 1992, we discovered the remains of a two-year-old female goshawk strewn over the forest floor, along with some breast feathers of a great horned owl, suggesting a struggle. Only about half a pound lighter than the owls, goshawks are by no means easy prey. But there was other evidence indicating that an owl had fed on the hawk: some of the goshawk feathers were pinched and torn near the base, and there were owl droppings on the ground nearby. At the same time, an adult female owl was sighted 200 feet from the kill site.

In 1989 and 1990, when snowshoe hares were most abundant, only one of eleven monitored goshawk nests failed to produce fledglings. In contrast, in the following two years, four out of eight nests failed, all because of predation at the nest. In 1991, for example, a week after locating an active goshawk nest, we found the nest silent, with the remains of an adult female goshawk scattered underneath the nest tree, along with four great horned owl feathers. Shortly thereafter, Christoph Rohner, an ecologist from the University of British Columbia, discovered what was left of a leg bone belonging to an adult female goshawk in one of the owl nests he was studying about a thousand yards away.

The lynxes and foxes and raptors of the Canadian north woods are not the only predators to turn on one another. In Africa's Serengeti, Tim Caro and his colleagues have shown that predation by lions and hyenas is by far the largest cause of death in cheetahs. Among smaller organisms, such as arthropods, interpredator predation is often the norm. In freshwater streams, dragonfly nymphs frequently prey on the young of smaller dragonflies. And predator–prey relationships may flip-flop, as, for instance, when animals grow from larval to adult stages.

This kind of predation may have far-reaching effects on how natural communities function. When lynx turns on lynx, for example, does this take pressure off the depleted hare population and slow its decline? And what is the effect on other prey in the boreal forest, such as squirrels and voles? With all these unanswered questions, we are certain that we will be testing our ideas about the boreal ecosystem for many seasons to come. We have learned one thing, though: the better we understand even a relatively simple food web, like that in the northern forests, the more we realize how complex it really is.

Mark O'Donoghue is the field coordinator, Elizabeth Hofer the predator biologist, and Frank I. Doyle the raptor biologist for the Kluane Boreal Forest Ecosystem Project.

THIS VIEW OF LIFE

Evolution by Walking

A stroll through the Museum's new fossil mammal halls teaches the visitor that life's history is not linear but branching

by Stephen Jay Gould

Think of the great dramatic conflicts between women and sinister forces—Fay Wray and King Kong, Sigourney Weaver and the Aliens, or even, if your tastes wander to culture in the canon, Portia and Shylock (even more disturbing, in its anti-semitism, than gorillahood or parasitic alienation, and unredeemed by Portia's status as the strongest feminist in the group). But I still cast my vote, in this genre, for Raquel Welch and the antibodies in *Fantastic Voyage*. As part of a scientific team reduced to microbial size and injected into a human body, Ms. Welch leaves the vehicle for an internal "space walk" and then must struggle with a horde of murderous antibodies who correctly identify her as nonself and merely try to do their appointed job.

I give the nod to Welch and the antibodies because she embodied a small but distinguished genre of pedagogy that I find particularly effective in using the visceral to grasp the cerebral: scaling a human being up or down in order to illustrate a concept by moving the body directly through a process or phenomenon. I have, for example, been a pawn (literally) in a very large game of chess—and I really did understand the game better after I moved doggedly forward, slipped cleverly on a diagonal to murder a brother of another color, and finally succumbed to the ecclesiastical sweep of a distant bishop along the same diagonal.

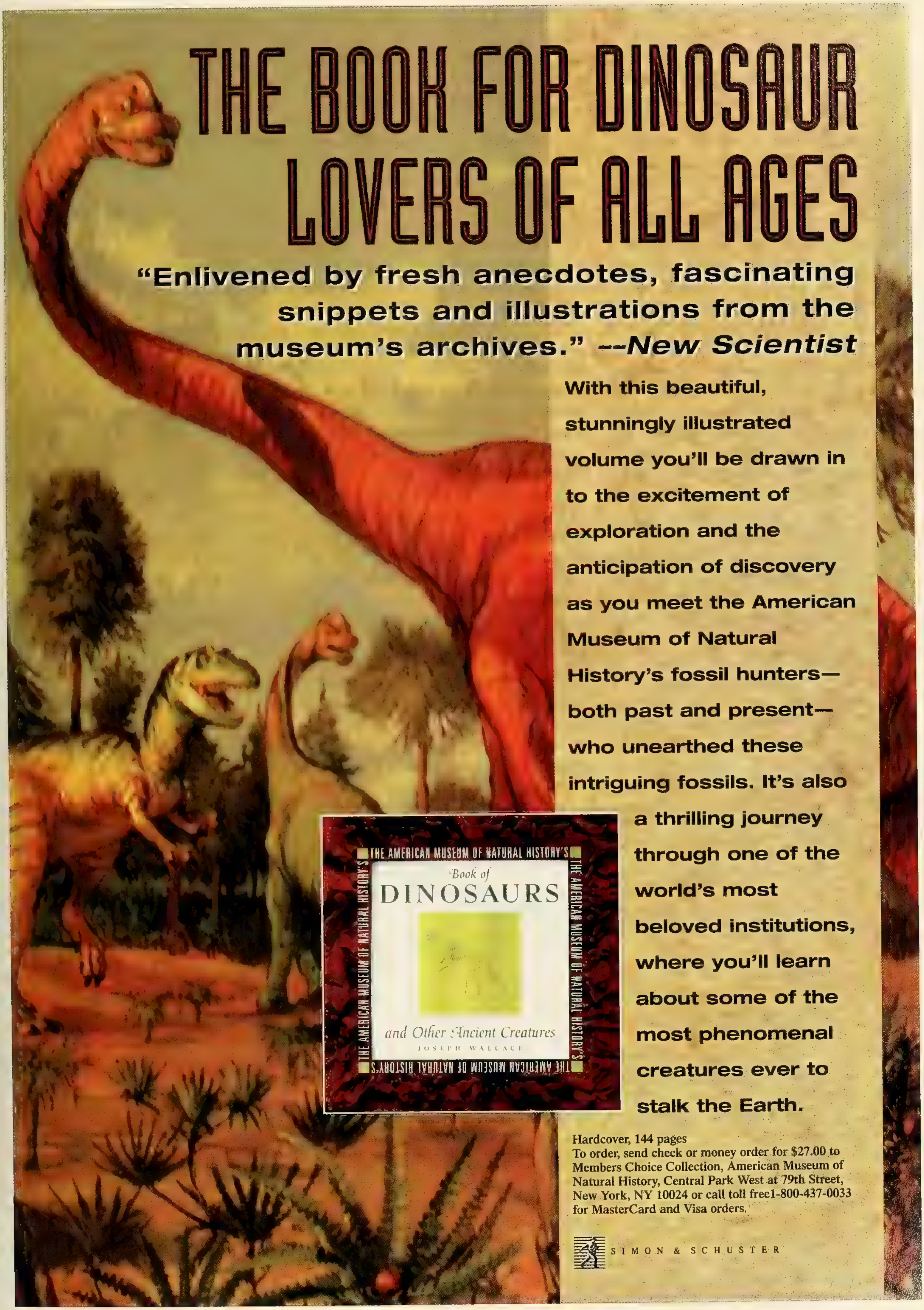
Similarly, museum exhibits on the heart may treat each visitor as a blood cell moving through corridors shaped as vena cava and aorta, into rooms modeled as auricles and ventricles. Examples can also become more abstract but shaped to the same end. In a great classic of modern popular science writing (*Mr. Tompkins in Wonderland*), George Gamow beautifully illustrated the arcana of relativity and quantum theories by granting them control over ordinary human activities at the scales and times of our own bodies, rather than at tiny sizes or great speeds beyond our experience. (His quantum tiger hunt, for example, is a lovely exercise in frustration, as gunners can only fire at a probability spectrum of tiger positions and hope for the best.)

I write this essay to praise the newly opened halls of fossil mammals at the American Museum of Natural History. (One should be properly leery of encomiums published in house organs, for the same museum publishes this magazine, but I am a cussedly independent soul, and a financial freelancer in this context—and I will also discuss my criticisms.) I admire the hall because it follows the human chesspiece strategy of pedagogy in teaching us about evolutionary trees by organizing the entire hall as a central trunk and set of branches—and then, so to speak, placing our brains in our feet and letting us learn by walking. Moreover, the chosen geometry of evolutionary organization in this new hall of mammals violates our traditional picture of life's history, thus illustrating in an unusual scale (large) and mode (visceral) a favorite theme of these essays and an important principle in the history of science: the central role of pictures, graphs, and other forms of visual representation in channeling and constraining our thought. Intellectual innovation often requires, above all else, a new image to embody a novel theory. Primates are visual animals, and we think best in pictorial or geometric terms. Words are an evolutionary afterthought.

The power of pictures, as epitomes or encapsulators of central concepts in our culture, may best be appreciated in studying what I like to call canonical icons, or standard images that automatically trigger a body of associations connected with an important theory or institution in our lives. The power of canonical icons is greatly enhanced by our highly sophisticated neurological capacity to abstract, process, and distinguish images based on small differences in form. We are particularly good at simple shapes with defining features and clear symmetries—hence the skill of the caricaturist in knowing that we will all recognize a famous figure by exaggeration of one or two key traits.

As I write this essay in December, I think of two simple shapes in bilateral symmetry (the branched menorah as a hemisphere and the Christmas tree as an isosceles triangle) and another in radial symmetry (the star of David with six points and of Bethlehem with five) and consider the power of such simple imagery to provoke immediate recognition and then to evoke emotions of great depth and even danger (for we may as easily be led to tears as to a march into battle). And I remember just how disturbing a departure from canonical iconography can be. For example, as a Jew with no particular stake in the matter, I felt visceral distress when I first saw the beardless Jesus of Byzantine imagery. Distress then triggered thought—another source of iconography's power—and I recalled that we know absolutely nothing about the physical appearance and, for that matter, preciously little about the actual existence of the historical Jesus. Yet a tall, gentle, bearded Caucasian savior has supported the prayers and intentions of billions.

All scientific theories call upon canoni-



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cal icons for their illustration (and, often, even for their definition), but my field of evolution and the history of life has been more dependent than most, hence my interest in this theme. My sensitivity has been heightened because all canonical icons in my profession have presented the same encompassing, but fallacious, view based on social traditions and psychological hopes—namely, the idea of progress as an organizing principle—rather than on the fossil record. Exposure and correction of such iconography therefore assumes special importance for paleontologists.

The canonical icon of life's history presents a series in linear order, starting with something deemed primitive and old and ending with *Homo sapiens*. These linear arrays may take many forms: a vertical sequence of increasing complexity (the infamous ladder of progress); a horizontal order from stooped ape to upright human (the literal "march of evolutionary advance" always depicted left to right, as we read, although the only Israeli example that I have seen—a recent Pepsi ad—runs right to left); a sequence of exhibits as we walk down a rectangular museum hall; or the order of chapters in a conventional textbook, with protozoans first and mammals last.

As a first, and surely welcome, corrective often advocated in these columns, we can switch our icon from ladders to trees and gain accuracy while shedding some prejudices. But this basic topological shift does not solve the problem of progressivist bias for another iconographic reason: trees have conventionally been drawn with their own, more subtle set of geometric devices for depicting evolution as continuous advance. The traditional evolutionary bush is a "cone of increasing diversity," an inverted Christmas tree with a central trunk of common ancestry, just a few branches near the base, with each as the primitive precursor of later flowerings, and steady increase in both number of branches and horizontal spread into a verdant canopy at the tree's summit.

Upward growth, according to the captions for most evolutionary trees, only means movement from older to younger periods of geological time, but up and down also stands for good and bad in our mythology (beautiful flowers on thin branches versus dirty and gnarly roots; the brain versus the bowels; heaven and hell; Valhalla and Nibelheim)—so up on the tree is usually conflated with more progressive, and the tree of life, when drawn as a cone of increasing diversity, mimics the ladder of progress and tells the same false tale.

If fire must be fought with fire, then this great fallacy at the core of our canonical icons for evolution can only be corrected by developing and popularizing a more accurate picture. Trees rather than ladders bring us part of the way, but trees may also be drawn restrictively to support the central fallacy of predictable progress. How, then, can we draw a tree differently, to emphasize the genealogical connections that define evolutionary relationship, while eschewing the conflation of upward growth with progress and avoiding the implication that trees always spread out toward more and better as they grow up. This search for a new iconography is no minor task, no little frill to an effort that can only be fulfilled in the verbal mode. Icons are primary molders of our thoughts, and the search for fundamentally new representation is one of the most important efforts a scholar can make.

Several of us have tried to develop new icons to record contingency and unpredictability as central themes in the history of life. But I write now to praise my colleagues at the American Museum of Natural History for carrying the task further in the unusual context of an exhibition hall.

Just as paper provides a substrate for a variety of icons that embody the central fallacy of predictable progress—ladders, marches, cones of increasing diversity—so, too, does the space of a conventional museum's exhibit on the history of life record the same biases. Most museum halls are rectangles with a preferred linear flow of visitors in one direction along the major axis. All exhibits on the history of life that I have ever seen in any museum anywhere in the world organize the space provided in one of two ways—and both, however unconsciously and often without explicit signage, embody the bias of progress as a central principle for arranging organisms.

One favorite scheme simply organizes fossils in temporal order: oldest at one end of the hall, youngest at the other. Such a scheme would not necessarily (really should not) record the bias of progress, for geologically young does not mean anatomically complex, and bacteria still rule the world today, as they always have since life's beginnings. Rather, temporal order records the bias because museum exhibits construe arrangement by time in such an oddly restrictive and grossly distorted way. They begin with an alcove of invertebrates, followed by a display of fossil fishes, then amphibians, then reptiles (including dinosaurs), then mammals, and finally human mammals.

All the fossils may be in temporal order, but what a peculiarly biased set of choices! After all, invertebrates didn't go away or didn't stop evolving once fishes arose. And fishes didn't stagnate just because one odd lineage crawled out on land. The most important event in all of vertebrate evolution (at least as recorded by number of modern species) must be the rise of the Teleosti, or so-called higher bony fishes, for more than half of all living vertebrate species are teleosts. But this great group of fishes arose and spread late in geological time during the reign of dinosaurs on land—so this cardinal event is either not shown at all or relegated to a little space at the "bad" end of the hall.

In other words, temporal order is not construed as a set of representative samples for all animal groups through time, but as a sequential tale of the most progressive organism at any moment, with superseded groups dropped forever once a new "ruler" emerges.

The other major organizing principle follows much the same scheme, but doesn't even try to present a defense in terms of temporal order. This second strategy just announces that life will be presented as a modern morality play of movement from lower to higher. Dinosaurs come before mammals (even though both groups arose at the same time and mammals lived throughout the dinosaurs' reign) because dinosaurs were dumb, lumbering, and primitive; while mammals come last because they are us (more elaborate justifications may be given, but do not doubt this bottom line).

In imagining how an alternative and challenging iconography might be constructed, I am reminded of the stunning impact that a simple device in a fine book once had upon me. When I studied vertebrate paleontology as a graduate student, we used Ned Colbert's classic textbook, *The Evolution of Vertebrates*. I shall never forget the disturbing sequence of his chapters on mammals. He devoted a section to each of the twenty or so mammalian orders, and he presented them in linear sequence as books must do. But he treated primates, including humans, fifth rather than last. In other words, he discussed the rise of australopithecines, the emergence of *Homo erectus*, and the interactions of Cro-Magnon and Neanderthal in Europe before he discoursed on the evolution of pigs, elephants, and sea cows.

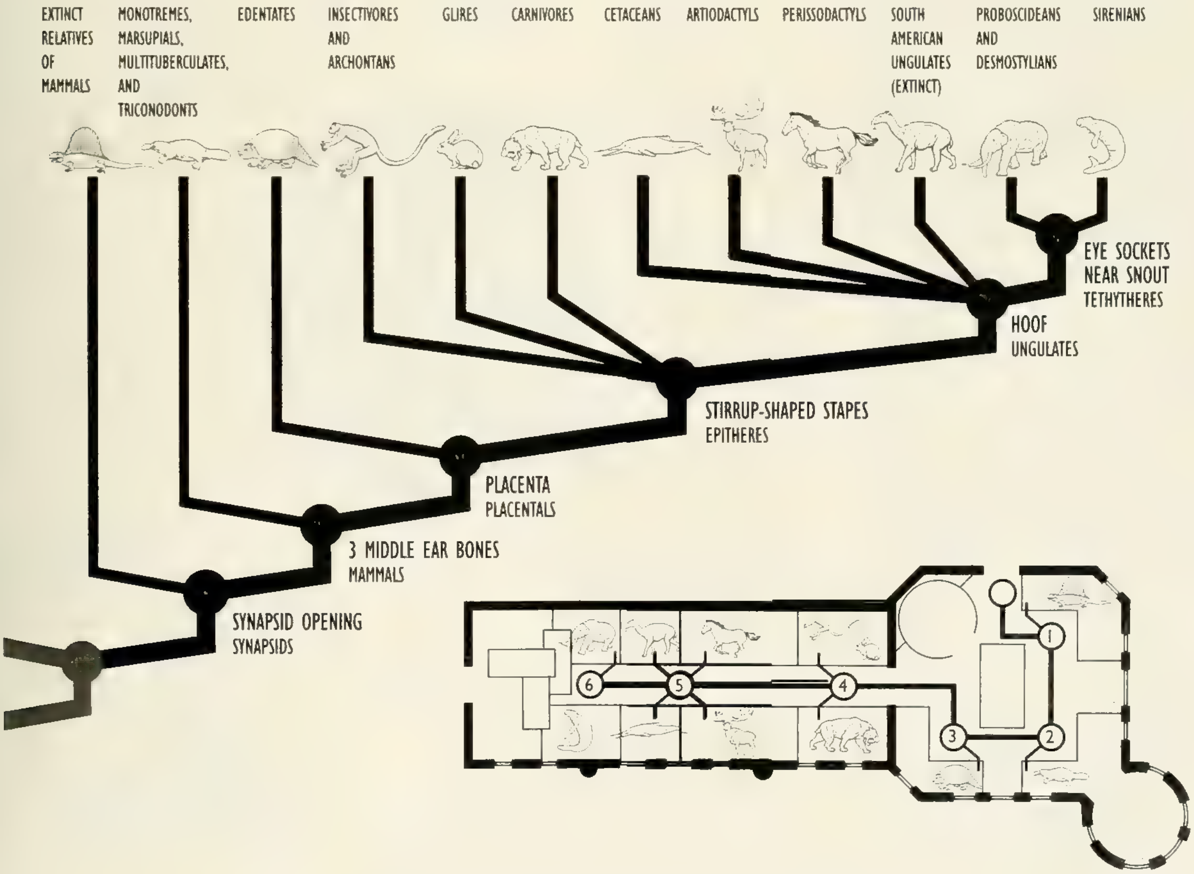
I was discombobulated and thrown into confusion at first, but then I started to think—and praise be to any scholar who can so provoke a neophyte out of his field's conventions. Why are humans always treated last? After all, although we arose late in geological time, other mammalian groups emerged still later. And we are not, by any a stretch of anatomical imagination, particularly far along the sequence of mammalian branches, for we still sport many original mammalian features that later-branching groups lost (including five discrete digits on each hand or foot, all with nails retained).

I then realized what Colbert had done—and his simple device was truly brilliant. He had arranged his chapters by order of branching, not by later degree of anatomical "achievement" (usually misinterpreted in human terms). Primates had branched early in the history of mammals, so their chapter comes near the beginning—no matter what certain peculiar primates later achieved in elaborating one particular organ to an unprecedented degree that, ultimately, may or may not do themselves and the rest of the world much good.

The fourth floor of the American Museum of Natural History was the shrine, the principal magic place, the sanctum sanctorum of my youth. I first visited with my father at age five and decided right then to dedicate my life to paleontology. I went back to the dinosaur and fossil mammal halls almost monthly throughout my childhood, right to the end of high school. I then left New York for undergraduate studies, but returned to do my Ph.D. work at the Museum. I loved the old halls, but they had become shabby and outdated. So I did not lament when they closed a few years ago for a thorough rethinking and redoing.

We must wait a while for the renovated dinosaurs, but the two halls of fossil mammals reopened in 1994. I do not love everything about them. I miss the cases crowded chockablock with titanotheres, while, for the restored murals of Charles R. Knight, with their beautiful bright colors rescued from overlying layers of varnish, grime and smoke, I can only make comparison with before and after at Michelangelo's Sistine Chapel (*see* "New Days for Old Knights," *Natural History*, October 1993). But for all my ambivalence on certain points, I offer unstinting praise for the intellectual concept behind the entire presentation. My colleagues have actually done it (writers are trained never to use such indistinct words as *it* in such a context—but this is the big "it," the only "it"). My colleagues have ordered all the fossils into an unconventional iconographic tree that fractures the bias of progress. They have created this new icon at gigantic scale, so that we can perambulate along the tree of life and absorb the new scheme viscerally by walking, rather than only conceptually by reading. They have, in short, taken Colbert's radical idea and arranged all the fossils in terms of their branching order, not their later "success" or "advancement." Groups that branched early appear early in the hall, even if they later diversified to a dominating degree (rats and bats) or generated lineages that we regard as particularly complex or advanced (primates). Sea cows and elephants are at the end of the hall; horses are in the middle, and primates near the beginning.

Since this essay extols iconography, it would be fatuous of me to praise this innovation with words alone. So consider the diagrams in the guide pamphlet that the


EXTINCT RELATIVES OF MAMMALS
MONOTREMES, MARSUPIALS, MULTITUBERCULATES, AND TRICONODONTS
EDENTATES
INSECTIVORES AND ARCHONTANS
GLIRES
CARNIVORES
CETACEANS
ARTIODACTYLS
PERISSODACTYLS
SOUTH AMERICAN UNGULATES (EXTINCT)
PROBOSCIDEANS AND DESMOSTYLIANS
SIRENIANS
EYE SOCKETS NEAR SNOUT
TETHYTHERES
HOOF
UNGULATES
STIRRUP-SHAPED STAPES
EPITHERES
PLACENTA
PLACENTALS
3 MIDDLE EAR BONES
MAMMALS
SYNAPSID OPENING
SYNAPSIDS
1
2
3
4
5
6

The floor plan (bottom) of the American Museum's new fossil mammal halls and the branching cladogram (top) on which it is based

Mammals and Their Extinct Relatives: A Guide to the Lila Acheson Wallace Wing; AMNH

Museum distributes to visitors. Note that a central dark line indicates the preferred route of passage through the two halls devoted to Mammals and Their Extinct Relatives. Major branching points, numbered one through six, appear along the line in temporal order of events during the history of mammals and their ancestors.

The technique used to identify these key branching points follows a theory and philosophy of taxonomy—called cladistics—that has motivated most of my colleagues at the Museum during the past twenty-five years, stimulating a fine body of important research. Cladistics classifies organisms in nested hierarchies based exclusively on their order of branching. (I should say that I am quite agnostic about this theory, so I do not write as a shill.)

The new, treelike icon constructed from these branchings is called a cladogram. The major, sequential branches on the cladogram are defined by traits that arose since the last branching point and have been held in common by all subsequent lineages on this branch of the tree (such traits are called shared-derived, or—if jargon attracts you, and this field has invented the most God-awful argot—synapomorphic, which means the same thing). For example, the earliest mammals did not form a placenta for their embryos and some modern groups—the egg-laying monotremes (platypuses and echidnas) and the pouch-bearing marsupials—are offshoots of these preplacentals. The placenta evolved after monotremes and marsupials branched off the main stem, and all subsequent mammals bear placentas. The placenta is therefore a shared-derived character of later mammals, and monotremes and marsupials therefore achieve their early position in the Museum's hall, for they must be placed before the branching point marked by acquisition of the placenta.

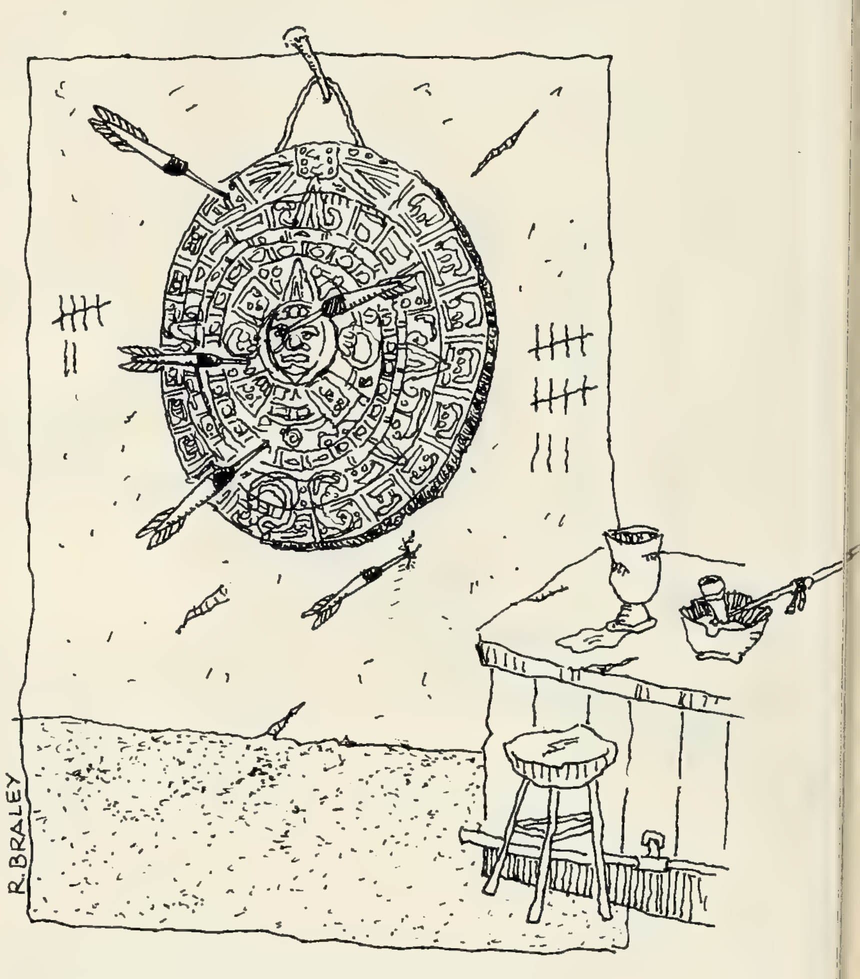
To illustrate how sequences of shared-derived characters can be used to build an icon of nested branchings based solely on temporal order of bifurcations, and not on perceived progress or increasing complexity, let me cite the example presented in the visitor's pamphlet:

> Sharks, salamanders, lizards, kangaroos, and horses all have a backbone composed of vertebrae and belong to a large group called vertebrates. Of the animals mentioned, only salamanders, lizards, kangaroos, and horses have four limbs. So they are more closely related and belong to a group called tetrapod, meaning four-footed. Within tetrapod, lizards, kangaroos, and horses develop in water-tight eggs that are either laid by the mother or are retained inside the mother until the embryo is born. The watertight membrane inside the egg is called the amnion, so lizards, kangaroos, and horses belong to a group called amniotes. Only kangaroos and horses produce milk for their young and have three bones in their ears to conduct sound vibrations. So they are more closely related and belong to a group within amniotes called mammals.

We might continue by using the placenta to group horses with all later mammals and to place kangaroos on a preplacental branch.

A walk in suggested order through the Museum's two halls of fossil mammals becomes an excursion along the main route of the cladogram. A sequence of six key shared-derived characters marks the temporal order of branching and establishes the genealogically defined topology of nested groups within more inclusive groups. Lineages that branch off before the acquisition of a new shared-derived character appear, in the exhibition hall, before the node defined by that character—as in my example of monotremes and marsupials before the evolution of placentas. The exhibit walks visitors through mammalian history according to six features that define a genealogy of branching, not a ladder of putative advance.

1. *The synapsid opening.* Late in the Paleozoic era, more than 250 million years ago, a group of reptiles developed an opening in the skull behind the eye socket. This feature apparently evolved but once, and all subsequent creatures with such an opening share a unique genealogical heritage with the common ancestor that first evolved this opening. All mammals possess this feature (muscles that close the lower jaw attach to the skull around this opening), as do members of ancestral groups formerly placed among the reptiles. For example, the famous pelycosaurs (early tetrapods, such as *Dimetrodon,* with sails on their backs, featured in all kiddie plastic "dinosaur" sets from cereal boxes)



Recent excavation by archeologists in Mexico disproved the Aztec Calendar Theory.

are synapsids and therefore genealogically closer to mammals than to dinosaurs. By placing pelycosaurs at the foot of the mammal hall, as members of the first branch following acquisition of the synapsid opening, we do not stake a claim for their superior progress or greater complexity (I suspect, in fact, that true dinosaurs were markedly more capable creatures in all important functional ways) but only affirm the genealogical link of pelycosaurs to all other synapsids, including mammals.

2. *Middle ear bones.* The two bones that articulate the reptilian jaw decreased in size and moved into the middle ear in mammals, where they joined the stapes (or stirrup, the only hearing bone in reptiles) to become the malleus and incus (hammer and anvil) of our middle ear. This highly distinctive feature, ascertainable in the fossil record, defines the branch point separating true mammals from their ancestors. In the new hall, monotremes and marsupials branch off here because they evolved the three ear bones (feature two), but not the subsequent placenta (feature three).

3. *Placenta.* As discussed above, the placenta evolved after monotremes and marsupials branched off, and all subsequent mammals possess this shared-derived character. In the hall, edentates (sloths, anteaters, and armadillos) branch off here because they have placentas (feature 3) but not feature 4.

4. *The stirrup-shaped stapes.* In reptiles and early mammals, the stapes is a simple rod. But later on, at this fourth bifurcation, a hole evolved in the stapes (an important blood vessel goes through it), and all subsequently evolved mammals possess such a perforated (or stirrup-shaped) stapes. At this key conceptual position in the exhibition, all mammals with a stirrup-shaped stapes, but without subsequent feature number 5 (the hoof), branch off and thereby secure their location in the sequence. Several major groups diverge at this bifurcation, including carnivores, rodents, bats, and—note the parochial key to a conceptual revolution—primates. Thus, human fossils are properly housed at the beginning of the second hall, in the appropriate position of their genealogical branching, and not at the apex of the icon, or the end of the story.

5. *The hoof.* At a later point, toes coalesced to form hoofs in the ancestry of subsequent mammalian groups. Thus, the major hoofed orders occupy this large central area in the second hall (horses, rhinoceroses, and tapirs among the perissodactyls, or odd-toed hoofbearers; cows, pigs, sheep, goats, giraffes, deer, antelopes, and many others in the phenomenally diverse group of artiodactyls, or even-toed hoofbearers; a group of distinctive and extinct South American forms; and whales, which evolved from hoof-bearing ancestors, despite their later loss of this feature for obvious reasons of aquatic adaptation).

6. *Eye sockets near the snout.* As a final shared-derived character, eye sockets move forward on the skull to a position near the snout—a feature defining the genealogical tie of elephants to sea cows and their relatives.

Consider the enormity of the conceptual shift embodied in this new icon based on a novel criterion for ordering groups: humans used to occupy the end of the hall, conceived as a pinnacle of progress and complexity, and defined by a criterion of dominion—our exalted brains. Sea cows now cavort at the end because they share, with elephants, a unique feature that evolved late in a sequence defining the major groups of mammals by their order of genealogical branching.

While I strongly praise this new icon for its iconoclasm—literally breaking the conceptual lock imposed by the old canonical drawings, all based on progress as the central feature of life's history—I must remain true to the theme of this essay: that all icons embody theories and are therefore capable of both breaking the conceptual locks of earlier, inadequate icons, and of introducing new (often subtle and unrecognized) biases of their own. Choose your cliché: we are on a two-way street; tit for tat; hoist by one's own petard. This new icon may dispel the prejudice of progress, but it also introduces a host of unfortunate restrictions and distortions based on the exclusivism of cladism as a philosophy of systematics. For cladism is not an accommodating or pluralistic theory, carefully balancing all legitimate concerns, but a zealous advocacy of one admittedly vital criterion: temporal sequences in branching order as the only proper way to depict relationships among organisms.

Two features of evolution, considered important by most professionals (myself included), must be marginalized, if not ignored outright, by cladistic icons: unique features evolved by single lineages and trends within groups that do not lead to further branching events. Unique features, called autapomorphies in the jargon, do not define branching points because they evolve within a single group. Cladists may like and acknowledge such features well enough, but the new icon grants uniqueness no space and no picture. And yet, such features epitomize much of the fascination for evolution among members of the general public and among specialists as well. We really do want to know what pelycosaurs did with their sails, saber-toothed tigers with their teeth, narwhals with their single tusk, duckbills with their duckbill, armadillos with their armor, and, dare I say it, humans with those damnable brains that keep me up writing essays at four in the morning five days before Christmas. And we want to understand sustained trends within groups: what about the famous story of fewer toes and higher teeth among horses? what about loss of hind limbs in whales and increasing brain size in humans? Again, cladists have little to say because transformations occurring on a single line of a cladogram have no iconographic representation within their system.

Moreover, and especially, such unique features and trends can only be treated in (literally) peripheral positions within the new hall of mammals—for attributes of single groups must be placed off the main line in the corners and alcoves devoted to later change within branching lines. The iconography that stirred us up now detracts from our legitimate interests by spatially marginalizing some of evolution's most fascinating phenomena.

But let me not carp. What liberating revision, in scholarship, politics, or any human endeavor, ever intruded upon our history fully formed and without growing pains? We are, after all, evolutionists, and we do believe in imperfection and change. The followers of Aristotle were called peripatetics because the "master of them that know" valued the linkage of cogitation and ambulation (the *peripatos* was the covered walk in the Lyceum). And Emerson made the same connection in his famous plea for a distinctively American excellence: "We will walk on our own feet . . . we will speak our own minds." Let us, then, praise the large scale of this delightful attempt to stir our mental machinery by exercising the historically prior and equally fundamental change that made human evolution possible: upright posture and bipedal locomotion.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

Blueprints, Bloody Ships, and Borrowed Letters

All inventions, from warships to alphabets, spread in one of two basic ways

by Jared Diamond

"There seems to be something wrong with our bloody ships today." Even if understated, the disappointment of British Vice Admiral Sir David Beatty was understandable. Poor Beatty had just watched two of his newest and most prized battle cruisers blow up within minutes of being shelled by German battle cruisers at the Battle of Jutland in 1916. Japanese Vice Admiral Nobutake Kondo's emotions after his own two battle cruisers were similarly dispatched by American warships off Guadalcanal in 1942 were not recorded, but were probably similar to Beatty's.

The varying fates of British, German, and Japanese battle cruisers illustrate two methods by which technology can spread. About 1905, British naval designers got the idea of building battleships that were faster than any then in existence; their method was to install enormous turbine engines while scrimping on armor. The first of these so-called battle cruisers was launched in 1908, and Britain permitted her then-ally Japan to copy the British blueprints. Naturally, though, that offer was not extended to Britain's arch rival Germany. Instead, nothing more than the basic idea diffused to the Germans, who had to work out all of the details themselves. As it turned out, the German design provided for more armor than the British or Japanese prototypes had. Thus the British, rather than the German, battle cruisers blew up at Jutland.

Such courses of events generally recur in the history of technology and ideas. Someone invents something and puts it to use. How do you, another would-be user, then design something similar for your own use, knowing that other people already have their own model built and working?

At one extreme lies the option of "blueprint copying," or modifying an available detailed design, as the Japanese did to construct their battle cruisers. At the opposite extreme lies "idea diffusion," by which you (like German naval designers) receive little more than the basic idea and have to reinvent the details. You know that it can be done, and you are thereby stimulated to try to do it yourself, but your eventual solution may not resemble that of the first inventor's.

Recent historians have debated whether the Soviet Union's building of an atomic bomb was the result of blueprint copying (by spies) or idea diffusion (from the dropping of the American A-bomb at Hiroshima, which convinced Stalin that the project was feasible). Similar questions have been raised about wheels, pyramids, steam engines, and even the development of writing systems—a subject full of fascination and mystery.

As far as we know, on only two occasions in history have people invented writing entirely from scratch, without any available models for blueprint copying or idea diffusion. Those twin inventions were achieved by the Sumerians of Mesopotamia somewhat before 3000 B.C., and by the Zapotecs and/or Olmecs of Mexico just before 500 B.C. (I'll say later why I'm not counting ancient Chinese and Egyptians for the moment.)

Inventing a writing system must have been incomparably more difficult than adapting one. The first scribes had to figure out things that we now take for granted: how to represent sounds by symbols; how to decompose a continuous utterance into words, syllables, or phonemes; and how to recognize the same sound through all our normal variations in speech volume, pitch, and speed. Somehow, the first scribes achieved all that, without having in front of them any example of someone else's final result to guide their efforts. The task was evidently so difficult that all other literate peoples since then borrowed, adapted, or were at least inspired by existing writing systems.

Today, missionary linguists, trained by organizations such as the Summer Institute of Linguistics, are working on modified Roman alphabets for hundreds of New Guinean and American Indian languages. They are blueprint copiers, as were the government linguists who devised the modified Roman alphabet adopted in 1928 by Turkey. In a few cases, we even know something about the blueprint copiers of the remote past. Russia's Cyrillic alphabet, for instance, is descended from an adaptation of Greek and Hebrew letters devised by Saint Cyril, a Greek missionary to the Slavs in the ninth century A.D.; modified Cyrillic alphabets were created for many tribal languages of the former Soviet Union.

Much more often, we know nothing about the individuals who devised the famous alphabets of the past. But we can still compare later ancient alphabets with earlier ancient alphabets and deduce from letter forms which earlier alphabets served as models. That is how we can say with confidence that the Roman alphabet was adapted in the seventh century B.C. from the blueprint of the Etruscan alphabet, adapted in turn in the eighth century B.C.

TECHNOLOGY UPDATE

500 miles from nowhere, it'll give you a cold drink or a warm burger...

NASA space flights inspired this portable fridge that outperforms conventional fridges, replaces the ice chest and alternates as a food warmer.

By Charles Anton

Recognize the ice cooler in this picture? Surprisingly enough, there isn't one. What you see instead is a Koolatron, an invention that replaces the traditional ice cooler, and its many limitations, with a technology even more sophisticated than your home fridge. And far better suited to travel.

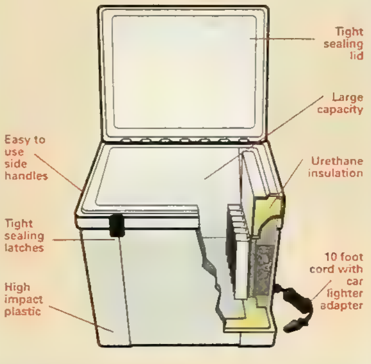
What's more, the innocent looking box before you is not only a refrigerator, it's also a food warmer.

NASA inspired portable refrigerator. Because of space travel's tough demands, scientists had to find something more dependable and less bulky than traditional refrigeration coils and compressors. Their research led them to discover a miraculous solid state component called the thermo-electric module.

Aside from a small fan, this electronic fridge has no moving parts to wear out or break down. It's not affected by tilting, jarring or vibration (situations that cause home fridges to fail). The governing module, no bigger than a matchbook, actually delivers the cooling power of a 10 pound block of ice.

The refrigerator from outer space.

The secret of the Koolatron Cooler/Warmer is a miniature thermo-electric module that effectively replaces bulky piping coils, loud motors and compressors used in conventional refrigeration units. In the cool mode, the Koolatron reduces the outside temperature by 40 degrees F. At the switch of a plug, it becomes a food warmer, going up to 125 degrees.



From satellites to station wagons. Thermo-electric temperature control has now been proven with more than 25 years of use in some of the most rigorous space and laboratory applications. And Koolatron is the first manufacturer to make this technology available to families, fishermen, boaters, campers and hunters– in fact anyone on the move.

Home refrigeration has come a long way since the days of the ice box and the block of ice. But when we travel, we go back to the sloppy ice cooler with its soggy and sometimes spoiled food. No more! Now for the price of a good cooler and one or two seasons of buying ice, (or about five family restaurant meals), all the advantages of home cooling are available for you electronically and conveniently.

Think about your last trip. You just got away nicely on your long-awaited vacation. You're cruising comfortably in your car along a busy interstate with only a few rest stops or restaurants. You guessed it... the kids want to stop for a snack. But your Koolatron is stocked with fruit, sandwiches, cold drinks, fried chicken... fresh and cold. Everybody helps themselves and you have saved valuable vacation time and another expensive restaurant bill.

Hot or cold. With the switch of a plug, the Koolatron becomes a food warmer for a casserole, burger or baby's bottle. It can go up to 125 degrees.

And because there are no temperamental compressors or gasses, the Koolatron works perfectly under all circumstances, even upside down. Empty, the large model weighs only 12 pounds and the smaller one weighs just seven. Full, the large model holds up to 40 12-oz. cans and the smaller one holds six.

Just load it up and plug it in. On motor trips, plug your Koolatron into your cigarette lighter; it will use less power than a tail light. If you decide to carry it to a picnic place or a fishing hole, the Koolatron will hold its cooling capacity for 24 hours. If you leave it plugged into your battery with the engine off, it consumes only three amps of power.

Limited time offer. Because Comtrad is bringing this offer to you directly, you save the cost of middlemen and retail mark-ups. For a limited time only, you can get this advanced, portable Koolatron refrigerator at the introductory price of $99. Call today to take advantage of this special promotional pricing. Most orders are processed within 72 hours.

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The versatile Koolatron is available in two sizes. The P24A holds 30 quarts and the smaller P9 holds seven quarts. An optional AC adaptor lets you use them in your rec room, patio or motel room. They plug into any regular outlet.

Koolatron (P24A) holds 30 quarts	$99	$12 S&H
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from a western Greek alphabet, itself adapted by the early eighth century B.C. from the Phoenician alphabet.

Every time that an existing alphabet served as a blueprint for a different language, some problems arose because no two languages have exactly the same sets of sounds. Some inherited letters may simply be dropped, since the sounds that those letters represent in the lending language do not exist in the borrower. The Greek letter *chi* was as useless to ancient Romans as to modern English-speakers because it represented a guttural consonant missing in both languages. The reverse problem, the need to devise letters to represent sounds present in the borrowing language but absent in the lending language, has been solved in several ways. Sometimes an arbitrary combination of two letters is used. For example, the English *sh* represents a sound absent in Latin and Greek, but Russians and other Slavs found a simpler solution by inventing a single new letter for *sh*. Our medieval ancestors also invented new letters when they created *j, u,* and *w*. Alternatively, a distinguishing mark may be added to an existing letter, such as the Spanish tilde *ñ* or the German umlaut *ö*.

Nowadays, linguists solve such problems easily because they can draw on their academic training, as well as on the accumulated experience of their predecessors. In the past, though, there have been some spectacularly botched efforts. My favorite example is the evident blueprint copying that led to the Linear B writing of ancient Greece. One would have to search hard through the history of technology for more flagrant proof that an inappropriately copied blueprint can be beautiful in concept but miserable in practice.

Linear B refers to the writing system employed between about the fifteenth and thirteenth centuries B.C. by the Mycenaean Greeks, whose siege of Troy was immortalized by Homer and whose royal tombs at Mycenae were rediscovered by Schliemann. At that time, many of the writing systems in the Near East were complicated and inconsistent mixtures of signs for syllables and for whole words. No rules specified which spoken syllables had written signs, or how to represent syllables lacking their own sign. In contrast, Linear B was logical, consistent, and neat. Apart from logograms (signs for whole words), its core was a set of about ninety signs for syllables. These represented the five vowels *a, e, i, o, u,* plus most possible combinations of each of twelve consonants (*d, j,* *k, m, n, p, q, r, s, t, w, z*) followed by each of the five vowels. For instance, there were separate signs for *da, de, di, do, du, ka, ke, ki, ko, ku,* and so on. Consistent rules stipulated how to write syllables not represented by a single sign.

Unfortunately, this beautiful, logical system was lousy for writing the Greek language. It ignored the fact that Greek had aspirated consonants (*ph, th, kh*) and corresponding nonaspirated ones (*p, t, k*), voiced consonants (*b, g*) and corresponding voiceless ones (*p, k*), as well as two separate liquid consonants (*l* and *r*). One set of syllabic signs covers *p, ph,* and *b* indiscriminately, another lumps *t* and *th,* another lumps *g* with *k* and *kh,* and still another lumps *l* with *r*. We know how confusing we find it when some Japanese people speak English without distinguishing *l* from *r*. Imagine the confusion if our alphabet did the same while similarly homogenizing the other consonants! It's as if we were to spell "rap," "lap," "lab," and "laugh" identically.

Compounding these omissions, Linear B did not record consonants at the end of words, nor did it record *l, m, n, r, s* when they preceded another consonant, even though such syllables were common in Greek. The only types of syllables that had their own signs were syllables consisting of consonants (C) followed by vowels (V). These were so-called CV syllables, such as the English *de* or *ba*. To write the CCV and CVC syllables that are common in Greek, Linear B resorted to tricks: write CCV as CV + CV, and write CVC as CV. Thus, the syllable *tri* was written by the sign for *ti* plus the sign for *ri;* the syllable *pos* was written by the single sign for *po,* ignoring the final *s;* and the Greek word *tripos,* as a result, was written with the signs for *ti, ri,* and *po*. That's as if we were to write "sprinter" as si-pi-ri-ne-te.

Linear B had so many built-in ambiguities that it was used only by accountants, who wrote little more than lists of goods and tenants. Not surprisingly, no literary trace of Linear B has survived. Would *you* have wanted to write love songs if "Plato loves Andromeda" came out "Pa-ra-to rove A-no-do-ro-me-da"?

How did the glorious civilization that was to produce the *Iliad* and the *Odyssey* develop such a wretched writing system? A clue is that more than half of the syllabic signs of Linear B are identical or similar to syllabic signs of Linear A, the still-undeciphered writing system previously used for the Minoan language. Mycenaean Greeks conquered Crete about the time that Linear A disappeared and Linear B appeared. The Minoan language probably lacked all those sound distinctions ignored in Linear B, and the conquering Greeks apparently adopted as a blueprint, with only minor modifications, a system that was well-suited to the Minoans. (Perhaps the transformation from Linear A to Linear B was accomplished in a single night by terrified Minoan scribes, still surrounded by the bloody bodies of their compatriots and ordered by their Greek conquerors to start keeping accounts in Greek, rather than in Minoan, before sunrise the next morning.)

If this interpretation is correct, we owe two of the greatest masterpieces of literature to this botched attempt at blueprint copying. The *Iliad* and the *Odyssey,* whose unique character as oral epic poetry depends upon their having been composed by illiterate bards for illiterate listeners, could never have arisen if Homer and Mycenaeans other than palace accountants had been able to read and write.

While working from a blueprint is the most straightforward option for transmitting technology, that option is sometimes unavailable. Blueprints may be kept secret or may be unreadable to someone not already steeped in the technology. Word may trickle out about an invention made somewhere far away, but the details may not get transmitted. Nonetheless, the knowledge that someone has achieved something may inspire others to devise their own routes to a similar outcome.

A striking American example is the origin of the system, devised in Arkansas in about 1820 by a Cherokee Indian named Sequoyah, for writing the Cherokee language. Sequoyah, a blacksmith, observed that white people made marks on paper, and that they derived great advantage by using those marks to record and repeat lengthy speeches. However, the detailed operations of those marks remained a mystery to him because (like most Cherokees at that time) Sequoyah could neither speak nor read English. He began by devising an accounting system to help him keep track of his customers' debts, drawing a picture of each customer, then drawing circles and lines of various sizes to represent the amount of money owed.

About 1810, Sequoyah decided to design a system for writing the Cherokee language, even though he did not know the principles of English writing. He again began by drawing pictures, but gave them up as too complicated and too artistically demanding. He next began to invent separate signs for each word, and again be-

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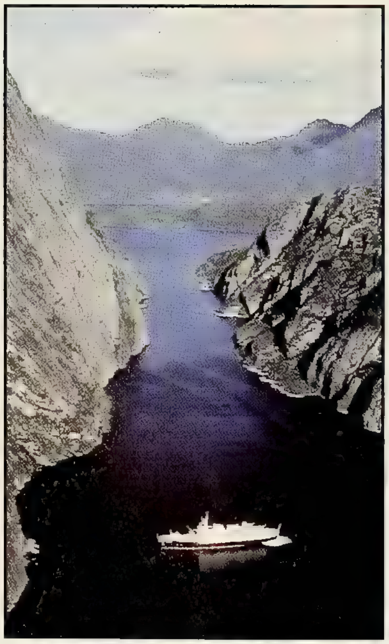

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came dissatisfied when he had coined thousands of signs and still needed more. Finally, Sequoyah realized that words were made up of modest numbers of recurring sounds—what we would call syllables. He initially devised 200 syllabic signs and gradually reduced them to 85, most of them for one-consonant, one-vowel combinations.

One source of the signs themselves was an English spelling book given to Sequoyah by a schoolteacher. He practiced copying the letters, and about two dozen of his Cherokee syllabic signs were taken directly from those letters, although with completely changed equivalences, because Sequoyah did not know what they represented in English. For example, he chose the shapes *D, R, b, h* to represent the Cherokee sounds *a, e, si,* and *ni,* respectively, while the shape of the numeral 4 was borrowed for the sound *se*. He coined other signs by modifying English letters and by inventing completely new shapes.

Sequoyah's syllabary is widely admired by professional linguists for its good fit to Cherokee sounds and for the ease with which it can be learned. To convince his skeptical fellow tribespeople, Sequoyah staged a public demonstration at which one Cherokee spoke a message to one of Sequoyah's pupils, who wrote it down and left the room. Then a different pupil came into the room and read the message. The skeptics were astonished that pupil after pupil could read the message that they had never actually heard themselves.

Within a short time, the Cherokees achieved almost 100 percent literacy. They raised funds, bought a printing press, had Sequoyah's signs cast as type, and began printing books and newspapers. Sadly, the Cherokees' literacy did not dissuade the U. S. government from forcing them in 1838, along with other Indians of the southeastern United States, to emigrate to Indian Territory (now Oklahoma). Georgia troops stormed the Cherokee newspaper office and hauled off the printing press.

The Cherokee syllabary remains the best-attested example of a writing system that arose through idea diffusion. We know that Sequoyah received paper and other writing materials, the idea of a writing system, the idea of using separate marks, and the forms of several dozen marks. But because he could neither read nor write English, he acquired neither details nor principles from the existing writing systems around him. Surrounded by alphabets that he could not understand, Sequoyah instead independently reinvented a syllabary analagous to those of the Minoans and Mycenaean Greeks.

With this well-documented example, we can conclude that some ancient writing systems are also likely to have arisen through idea diffusion, although we have no direct or detailed information about what happened. For example, the Ogham characters used in Ireland and parts of Celtic Britain from about the fourth century A.D. constitute an alphabet of five vowels and fifteen consonants. The *idea* of an alphabet had been familiar to the Celts for nearly a thousand years, through contact with Rome and other alphabetic societies. Yet the forms of the Ogham letters resembled those of no other alphabet in the world. They consisted instead of a line with between one and five other lines arranged perpendicularly above, below, or across the main line. These forms suggest origin in a five-finger system of hand signals. Some Celt who had evidently seen or heard of other alphabets figured out a novel way to put the idea into practice.

Although the ancient Sumerians and Mexicans may have been the sole peoples to invent writing independently, the Egyptians and Chinese invented *forms* of writing that certainly are unlike those of other systems. Didn't they also invent writing independently? The unique forms eliminate the possibility of origins based on blueprint copying. However, they don't eliminate explanations based on idea diffusion, because we've just seen that some writing systems (such as Cherokee and Ogham) designed new sign forms while borrowing the idea of writing.

Egyptian hieroglyphs—which combined syllabic signs with word signs—suspiciously appeared in nearly full-blown form about 3000 B.C., at a time of intense trade between Egypt and Sumer. Sumerian writing, which had the same arrangement, can be traced further back over many centuries. Equally suspicious is the appearance of several other, apparently independently designed writing systems in Iran, Crete, and Turkey (so-called proto-Elamite writing, Cretan pictographs, and hieroglyphic Hittite, respectively) soon after the rise of Sumerian and Egyptian writing. While each of the systems used distinctive sets of signs not borrowed from Egypt or Sumer, the peoples involved could hardly have been unaware of the writing practiced by their neighboring trade partners.

It would be an astonishing coincidence if, after millions of years of illiteracy, all those Mediterranean and Near Eastern societies had just happened to hit independently upon the idea of writing within a few centuries of one another. I suspect that the Egyptians, Elamites, Minoans, and Hittites received the idea from the Sumerians and their successors, but made no use of a blueprint and instead worked out the details for themselves.

As for Chinese writing (of which the first preserved sample dates from about 1300 B.C.), it too has unique local signs and some unique principles, and China lies thousands of miles east of Sumer. Yet writing was established in India, halfway between Sumer and China, by at least 2200 B.C. Did China remain truly unaware of Indian writing for at least 900 years and reinvent writing completely independently? Or does Chinese writing, which remains unsurpassedly original among writing systems in its beauty and its integration into art, constitute yet another example of idea diffusion? As battle cruiser design ironically illustrates, receiving the bare idea without the detailed blueprints may sometimes result in a better product.

Jared Diamond is a physiologist and evolutionary biologist at UCLA Medical School.

Indian Woman, Chris Roberts photo • Makoshika State Park, Wayne Mumford photo

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Shakey Lakes, Michigan

by Robert H. Mohlenbrock

Forests of oaks and pines now cover the sandy uplands on either side of the Menominee, a river that flows along the border between Michigan and Wisconsin. But when John Mullett and other government surveyors explored this area in 1848, they described much of it as "burnt plains." This phrase suggests that they saw areas of open prairie or, more likely, tree-studded savanna that had been subjected to periodic fires. In the past few years, Michigan botanist Don Henson, a former student of mine, has helped resurrect this habitat on some of the land belonging to Michigan's Escanaba River State Forest.

Henson's involvement began about ten years ago, when he came across a 1905 flora of Michigan compiled by W. H. Beal. The book mentioned that the prairie pasqueflower grew in the region near the Menominee River. Then Henson discovered that there were collections from the early 1930s of prairie plants from the vicinity of Stephenson, one of the towns in the area. These collections, which had been made by Carl Grassl, included such prairie and savanna species as big bluestem, prairie pinweed, and oval-leaved milkweed. His interest piqued by these finds, Henson began to explore the area around Stephenson.

At first, Henson observed what everyone else sees there—mile after mile of upland forests on sandy ridges. The predominant trees are northern red oak, Hill's oak, jack pine, and large-toothed aspen; beneath them grows a shrub layer of hazelnut, huckleberry, and snowberry. Among the wildflowers on the forest floor are such woodland species as Virginia anemone, pussytoe, lousewort, and arrow-leaved aster. But along forest edges in the vicinity of Shakey Lakes, a cluster of lakes on the Shakey River, Henson found an occasional plant of big bluestem, sand dropseed, western sunflower, and rough-leaved blazing star—all species more indicative of savannas than forests.

The savanna species were most common where country roads had penetrated the forest. One explanation for their presence might have been that seeds had blown in from elsewhere and germinated in the disturbed roadside soil. This was conceivable, although the nearest savannas are more than one hundred miles away, in central Wisconsin. But the historical documentation, including the testimony from the nineteenth-century surveyors, suggested that savannas had existed locally. They could have disappeared because brush fires had been suppressed in the region for half a century. To retain their characteristic prairie grasses and prairie wildflowers growing beneath patches of scattered trees, savannas require periodic fires. Otherwise trees encroach upon them and they give way to forest.

Savanna fires result naturally from lightning strikes. In addition, human groups aware of the benefits of periodic burns have learned to set fires at the most propitious times of year. The land along the Menominee River served as a major home and passageway for Native Americans since prehistoric times, and these inhabitants probably burned the savannas regularly every spring and fall. They may have done so to improve the habitat for preferred game animals. In addition, the burning may have been a kind of cleanup effort to destroy decaying vegetation attractive to various pests, including insects.

The savannas were probably maintained in this way for thousands of years, until European American pioneers forced the Indians to vacate the area. The new settlers began to turn some of the area into farms and tree plantations. To enhance the growth of trees, fire was suppressed, and forests began to replace the savannas.

Persuaded that the region around Shakey Lakes had been savanna at one time, Henson discussed his findings with the Michigan Department of Natural Resources. In the spring of 1988, after considerable negotiations

Prairie grasses grow in after an experimental burn in a Michigan forest, above. Opposite page: Harboring a grasshopper, oak leaves frame the fading blooms of wild bergamot.

Robert Doepker

Shakey Lakes

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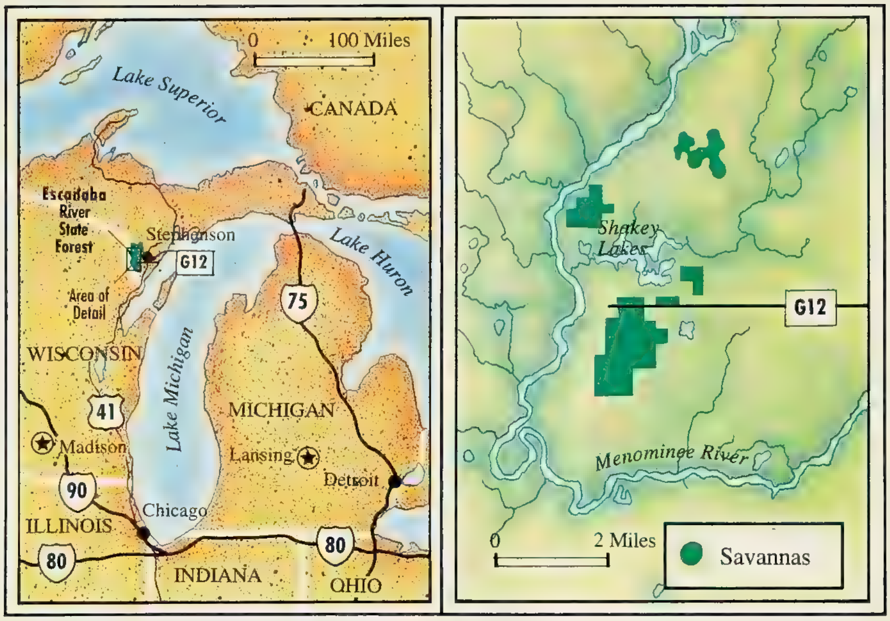
Joe LeMonnier



with the Michigan Division of Forestry, which manages some of the area around Shakey Lakes, and other interested groups and individuals, the Department of Natural Resources carried out two experimental burns of thirty acres each near Shakey Lakes.

Before the summer ended, savanna species popped up as rapidly as mushrooms do after a rain. June grass, big bluestem, little bluestem, two kinds of sunflowers, and the uncommon Hill's thistle suddenly abounded where previously they had been scarce. Arrow-leaved violet, spicate lobelia, large-flowered ground-cherry, and scarlet Indian paintbrush—all savanna plants never before recorded from this region of Michigan—came up and bloomed.

Apparently seeds of the savanna plants had been lying dormant in the soil beneath the trees for decades, and the fires helped their germination. In addition, since the fire killed or cleared away many of the trees, leaving only occasional specimens of oaks and pines, the savanna plants that germinated received adequate sunlight to flourish. In some areas, where the burning destroyed all of the trees, huge stands of big bluestem became dominant.

During the last several years, more potential savanna areas around Shakey Lakes have been burned. Currently, Shakey Lakes savannas consist of between 43,000 and 54,000 acres. But the future is uncertain. The Division of Forestry is under pressure to convert part or all of this acreage to red pine plantations for future timber production.

Since 1988, Henson has recorded more than one hundred prairie species from Shakey Lakes savannas, some of them exceptionally rare for this part of Michigan. Among the additional grasses that have appeared are Indian grass, witch grass, and two kinds of rice grass. The list of wildflowers now includes smooth aster and two kinds of narrow-leaved asters; brown-eyed Susan; bird's-foot violet, with its cleft leaves; orange hoary puccoon, with its woolly leaves; and wild bergamot, whose bright purple flower heads appear in late July.

Here and there across the savanna, the fires have provided suitable habitat for the prairie pussy willow, a four-foot-tall shrub and one of the few willows that live in dry, rather than wet, soil. In contrast, low areas in the savannas, which Henson calls swales, retain enough water following rains to support moisture-loving plants. In these small wetlands grow sedges and rushes, including the rare Vasey's rush.

The savannas' restoration has affected the animal life as well. Badgers, eastern hog-nose snakes, and fox snakes have become more common. If enough savanna areas can be reclaimed, naturalists may someday be able to reintroduce the prairie chicken, a flightless grouse not seen in Michigan since the 1960s. Today the nearest colony of these birds is found north of Madison, Wisconsin.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of public lands, especially the 156 U.S. national forests.

Orange hoary puccoon, with its woolly leaves, is one of the first prairie flowers to bloom in the spring.
Dick Scott; Visuals Unlimited

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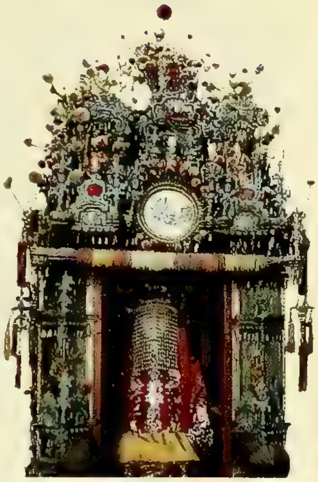

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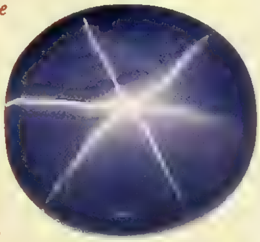

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Dictionary of the Proletariat

What's next?

by Roger L. Welsch

Relying on absolutely no information at all, I would guess that as many American homes have dictionaries as Bibles. Even the Dannebrog tavern has its battered and worn dictionary, used to settle arguments about anything and everything, because whatever the dictionary says must be right. There is no appeal from a dictionary. (Probably fewer people challenge the word of a dictionary than bend the Word of the Bible.)

You would think that given this official arbiter of language, this irrefutable authority, the meanings and spellings of English words would have settled down and stayed put. But they haven't. Language insists on varying and changing. Even the homogenizing influence of the mass media can't prevent it. Although television and radio come into every home, with every voice speaking the same words in the same way (except for country-western music stations, where even folks from Detroit sound as if they were raised on grits), language breaks free.

Old English teachers like me grade papers until we eventually become so agitated we no longer write such diplomatic comments as, "Please note: 'A lot' is two words, as are 'a little' and 'a few.' And it's 'all right' rather than 'alright.' I suspect you are perhaps operating under a false linguistic analogy with 'already,' which is quite another issue. Please correct your paper and resubmit it." Instead we explode with "How many times do I have to tell you dumb boogers that 'a lot' is two words! Get this straight or get out of my class, preferably out of this school! Maybe off of this planet." (Computer spell-checking programs, whatever their faults, have more patience.)

In calmer moments, however, I readily concede that it is not the English teacher but the students (and the farmers and street people and butchers and factory workers) who are more in tune with the natural processes of language. It may be "a lot" for me and it may be "all right" for most of you, but I'll bet that before the end of the next century, our current formulations will be listed in the dictionaries of the day as "archaic" or as "a less preferable alternative," while the current perversions will be "standard." (If I'm wrong, my great-great-grandchildren will, I know, be delighted to pick up the tab.)

The inevitable changes in language necessarily begin as mistakes, anomalies, mongrelizations, dreadful abuses, impossible distortions, idiotic affectations. And then, before long, there they are—the very forms being defended by old fogies like me. My favorite example is the current confusion over the word "next." Next is not a complicated idea for me. To me, next means . . . uh, next. This is Friday. Next Sunday is Sunday. So when and why did next suddenly (it seems sudden to me) get complicated? Now, when I say "next Sunday," there's this ruffle of confusion, and a whole script of questions to determine which "next Sunday" I'm talking about. "Do you mean this Sunday? Or next Sunday?"

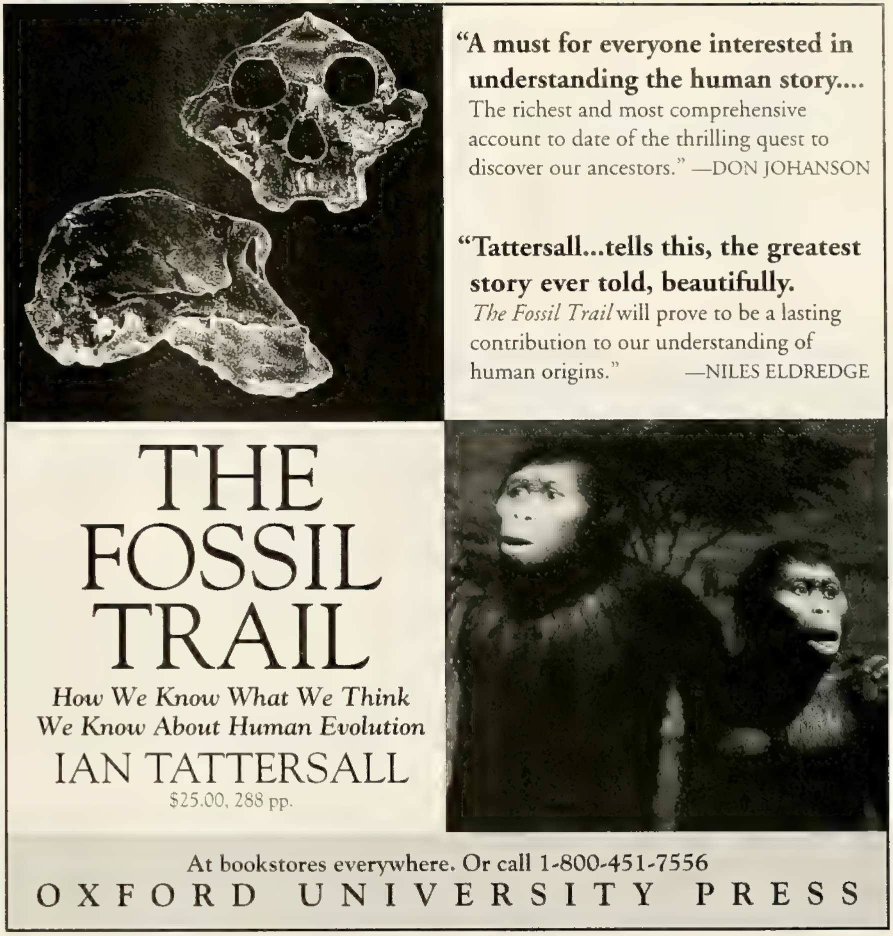
I think I said it: "Next Sunday." That's the nearest Sunday to where we are right now. And I ask again, "What's complicated about that?"

Actually, there's a lot (two words) complicated about that. It's all wrong. It's one of those terrible linguistic perversions some other English teacher ranted and raved about in the distant past. You know how we compare things—cold, colder, coldest; hot, hotter, hottest; close, closer, closest. Well, an earlier (Middle English) way of saying "close" was "nigh." It meant near. At least, it meant what near means now but didn't used to mean. Near, or rather ner, used to be the comparative form of nigh. So, nigh meant close and ner meant closer. Therefore, today, when we say "nearer," we are actually saying "closerer." And when we say "nearest," we are actually saying "closerest."

It gets worse. Or worser, depending on how you feel about linguistic liberation. The superlative form of nigh was—eeek!—next. So, instead of "close, closer, closest," speakers of Middle English said something close (or, one might say, nigh) to "nigh, near, next." Our current confusion over next Sunday—the idea that it may not be the nearest Sunday after all—would be enough to give a decent Middle Englishman the fantods.

"Fantods." Now, there's a great word—a perfectly lyric word that never made the grade in English, except with Mark Twain (which one could certainly argue, is making the grade in a big way). Language, we can see, defies not only convention, regulation, conservatism, and logic but can't even spot a good word when it comes down the pike. It really is enough to give you the fantods.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.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Spiders! an exhibition highlighting spider diversity, ecology, and behavior, will be at the American Museum of Natural History from Friday, March 17 through Sunday, June 4.

Arac

nomania!

by Robert Jackson

A camouflaged crab spider ambushes a bee that has landed on a flower to sip nectar. A female moth emits a chemical signal, or pheromone, to attract males, but this is not necessarily safe sex, because a bolas spider produces a similar chemical attractant, luring male moths to their death. A jumping spider approaches its prey, a tephritid fly, but then backs off because markings on the fly's wings give it the appearance of another jumping spider. Some species of spiders look remarkably like ants, a deception that has probably evolved because most predators find ants distasteful and avoid eating them.

The story of the spider is, in many ways, an insect story. Insects' origins trace back to the middle Devonian period, almost 400 million years ago, with spiders appearing on the scene soon afterward. Given the interlocking evolutionary paths taken by these two groups of similar-sized arthropods, people may be justified in calling both the spider and the insect just "bugs." Even professional entomologists sometimes see spiders as honorary insects, judging from the frequency with which these eight-legged bugs find their way into entomology journals and courses.

But with no wings, no antennae, no compound eyes, a cephalothorax instead of a separate head and thorax, and an extra set of legs, spiders are a different kind of animal. Their story is more than just an adjunct to the insect story. It seems to be a story with a recognizable theme—to see what an animal can do with silk. Only a few insects can make silk, but all spiders have in their abdomens silk glands connected to spigots on fingerlike appendages called spinnerets.

Many spider–insect interactions take place in an area built of silk—a web. Spider webs may be large or small; single-line or multiline; sheets, funnels, orbs, and many other shapes; sticky or nonsticky—a kaleidoscope of different designs for catching insects. Many spiders build webs that intercept insects walking on the ground, on tree trunks, or in vegetation. When insects evolved wings and took to the air, spiders went after them with aerial webs.

Using silk is, for the spider, more than web building, and many species—those that hunt on the move or by ambush—have dispensed with web building altogether. When they go on a hunt, these spiders routinely trail a silk dragline along. Many spiders retire to the safety of a silk nest to rest between hunting expeditions, to molt, and to lay eggs. They routinely wrap their eggs in silk, and some juvenile spiders have even used the material to achieve flight; they disperse from their mother's lair by floating on silk balloons.

For many spiders, courtship is an exchange of signals sent vibrating across the silk lines of their webs or nests, which become extensions of the spiders' sensory apparatus. Even before courtship begins, the spider's sex life is linked to silk. Although the male's testes open at a gonopore on the underside of his abdomen, his copulatory organs are on his palps, at the front of the body. To transfer sperm from gonopore to palps, the male first deposits it on a small sperm web, then, with his palps, absorbs the sperm from the silk.

There are other themes in spider evolution. As a rule, spiders use their fangs to inject venom into prey, but this is a rule with some interesting exceptions. For example, small web-spinning spiders called uloborids wrap up their prey so tightly in silk that they have lost the need for venom glands to immobilize their victims. Other examples include *Diores*, a termite-eating spider armed with poison-producing glands on its front legs, and scytodids, spiders that spit a gluelike substance that fastens their prey to any surface. Still other oddities include spiders that have evolved alternative modes of transportation, some swimming to catch prey underwater and others that flee from danger by turning into living wheels.

Most spiders have extremely poor eyesight, but there is a major exception, the jumping spiders, or salticids. The unique complex eyes of these arthropods give them visual abilities unsurpassed by any insect of comparable size. Some jumping spiders, for example, routinely use their keen eyesight to leap and intercept flying insects in midair. A male jumping spider no more than a fifth of an inch in length can use his eyes to dis-

Recently discovered in northeast Spain, this 138-million-year-old fossil spider was delicately preserved between layers of limestone. At the end of each leg, the special claws needed to manipulate silk threads were found, indicating that the web-weaving skills of spiders were well developed by the early Cretaceous.

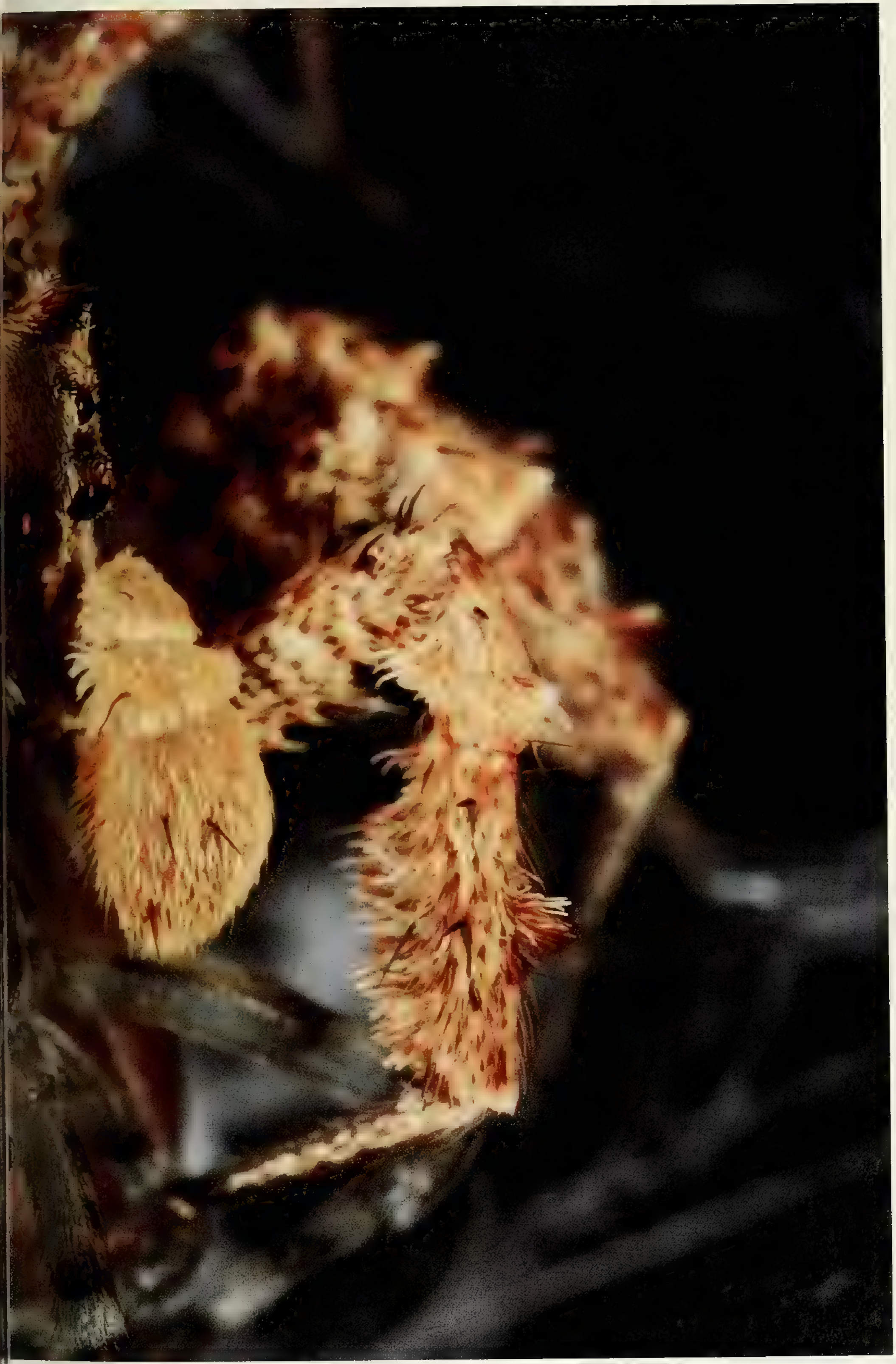
Paul A. Seldon

tinguish between an insect, a female of his own species, and a rival male at distances of as much as a foot away and respond appropriately by stalking the insect, courting the female, and intimidating the rival with a threat display. I have watched jumping spiders spot motionless prey and threaten their own image in a mirror. When exposed to images of mates on a television screen, they will reply with courting displays.

The salticids are my favorite spiders because, in their behavior, they defy the conventional wisdom that spiders are little more than instinct-driven automatons. The ultimate salticid is *Portia,* a genus of tropical jack-of-all-trades spider. To catch its prey, *Portia* can build webs, but it also hunts without them. Often the spider will even enter the web of another spider and capture it. These extraordinary raids demonstrate the spi-

der's problem-solving skills. For example, there are some webs that *Portia* prefers to enter from the top. If it spots such a web from below, a passing *Portia* looks around, then takes an indirect route through the vegetation to reach a point above the web—even when this means initially going away from the prey and venturing where the prey is temporarily out of view. Once in the web, *Portia* uses vibratory signals to deceive and manipulate the resident spider, often varying and combining these signals by trial and error to slowly coax the prey closer before attacking.

Insects and entomologists are far more numerous than spiders and arachnologists, but there are probably few animal groups with devotees more enthusiastic than the spider's. Read the articles assembled in this section of the magazine and see why.



Not limited to insect prey, many spiders hunt one another. The Australian jumping spider, Portia fimbriata, *shown here feeding on another arachnid species, vibrates other spiders' webs to lure their occupants into the open before attacking. It has even learned to mimic another species' courtship display, thereby enticing mate seekers into its clutches.*

Robert R. Jackson

Webs of Deceit

Much more than passive sieves to filter insects from the air, many orbs are fine-tuned to attract the spider's prey

by Catherine L. Craig

As the boat speeds along the Panama Canal, I recall the riot of yellow *Fotecia* flowers that dominated the forest canopy during the previous dry season. Now it is June, early in the rainy season, and the canal's banks are a patchwork of new, green leaves. As we near Barro Colorado Island, where the Smithsonian Institution's Tropical Research Station is located, I can see a blur of blue-violet dotting the shores of the cove, and as we pull into our slip, the vibrant hues become distinguishable as the last of the trumpet-shaped jacaranda flowers dropping into the water below. The distant blur of colors draws my attention from afar; the shapes and patterns that allow me to discriminate between flowers and plants at short range are just the sort of visual information that many pollinating insects use to find their food. My research on the island is focused on how spiders might incorporate these same visual cues in their webs to capture insect prey.

Because of their remarkable engineering, spider webs—particularly large orbs—have always held the interest of naturalists and laypersons alike. By taking a closer look at the silk itself, however, I have begun to see a new level of complexity in a web's design. All spiders produce silk, but the proteins that form silk threads vary considerably in their molecular makeup and serve a variety of purposes. The tarantula *Antrodiatus*, for example, spins a single kind of silk comprising just two different proteins. The silk is used to line the walls of the spider's burrow and encase its eggs. In contrast, spiders in the superfamily Araneoidea, the most evolutionally advanced of the web spinners, produce up to eight different kinds of silk. The type of silk they use to wrap their eggs, spin retreats, and lay safety lines during travel are similar to those produced by non-web-spinning species. In the orb, however, the spiders use a variety of silks made of several proteins working together (as in modern composite materials) to lend greater strength and flexibility to the web. While these orb spinners retain the ability to produce "old" silks spun by more primitive spiders, their "new" silks allow them to construct exceptionally large webs. This may be the reason araneoid spiders are almost forty times more numerous than the primitive orb-spinning spiders.

But the newer silks have another, more subtle, property that attracts my interest: they contain various proteins that render them translucent. I wanted to know if a relationship existed between the different light-reflecting properties of the silks and the strategies that the spiders used to trap insects. And because the different proteins in a spider's silk are encoded in the animal's DNA, I hoped to learn how the molecular evolution of the proteins in silk might be linked to the pattern of evolution at the level of the organism. Better silks to catch insects would lead to more successful species of orb spinners.

My colleague Gary Bernard, of the University of Washington, and I started in the laboratory, measuring and comparing the reflectance of spider silk spun by a range of species. Because reflectance determines visibility, we thought that this property might make some silks more effective than others for trapping insects. We also compared silk in webs spun by spiders in habitats with differing levels of light, such as open fields and the forest understory. Finally, I followed up with field studies to see how insects responded to different types of webs. Did variations in visibility, color, and pattern of the silk affect the insects' ability to detect and avoid webs? Were the more recently evolved silks indeed superior?

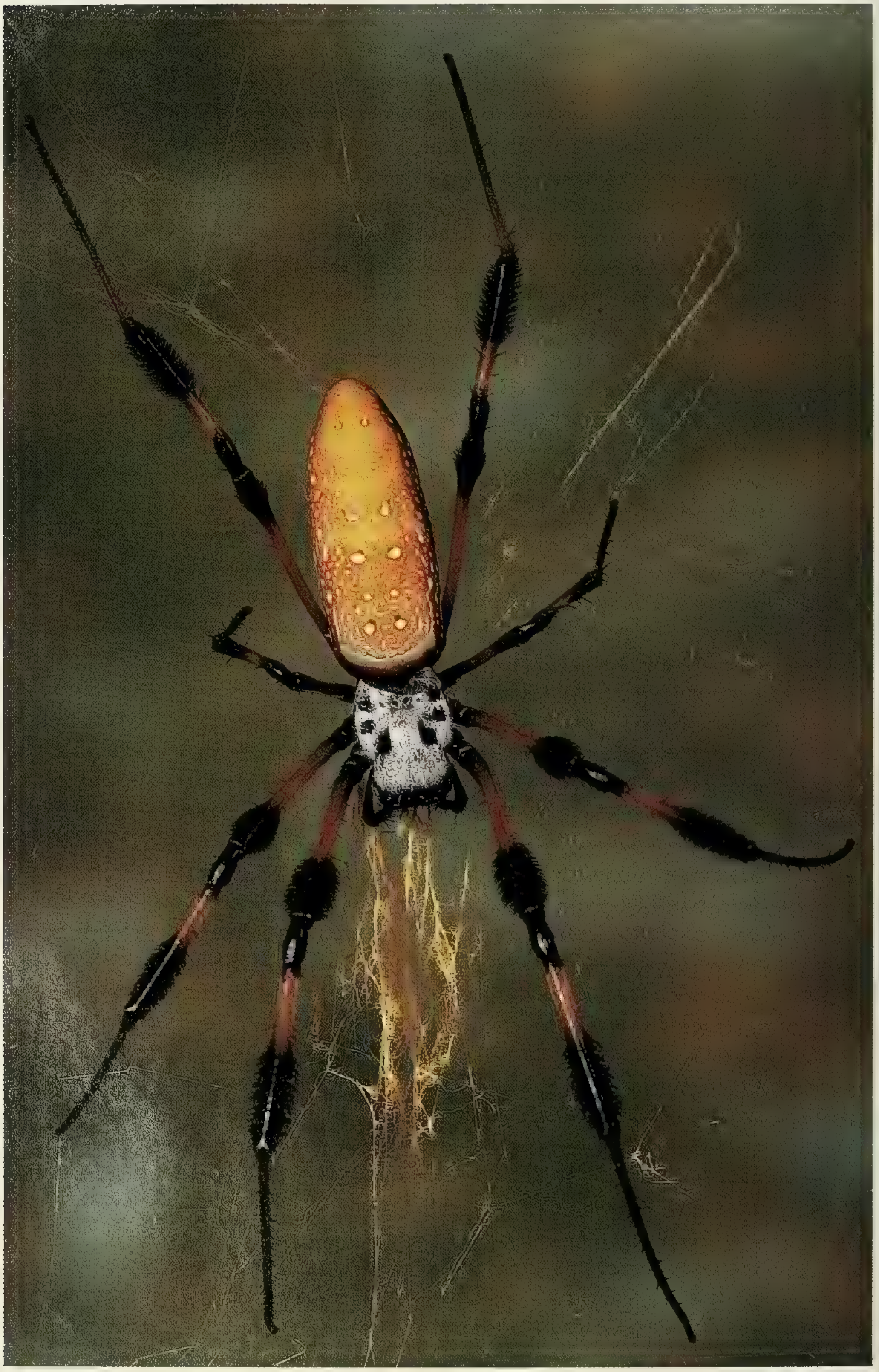
One spider that became a focus of our studies, *Nephila clavipes*, spins large orb webs in a wide variety of habitats and is found from southern Brazil to southern Florida. The spider produces yellow pigments that it adds to its silk, resulting in webs that are often so yellow that the spider is commonly called the golden orb weaver. Because the yellow pigments mask the natural reflectance of the silk and make the webs more visible, one might expect to find yellow webs in poorly lit forest sites. The silk in these forest webs, however, were only faintly pigmented, if at all, leaving them almost translucent and practically invisible. Instead webs in open, sunny areas had the most pigment, and were therefore the most conspicuous. When we moved golden orb weavers from one site to the other, we found that they adjusted the amount of pigment in their silk according to the changed light levels, suggesting that the golden webs are meant to be seen and are much more than passive filters "straining" insects that ride the wind. We wondered if the webs could actually attract prey.

To test this idea, my students and I studied how the stingless bee *Trigona fluviventris*, an insect commonly trapped by golden orb weavers, reacted to yellow webs and unpigmented ones in various light conditions. We marked the bees and trained them to drink from small dishes of sugar water that we set out for them. The bees returned to the sites daily, giving us the chance to

An orb web sags under the weight of morning dew. Orb weavers are among the most successful spider groups because they have evolved silks with remarkable strength and flexibility. Used in the web's frame and radial arms, such silks make large orbs possible.
David Overcash

test their reaction to webs that we had collected in hoops. The webs were placed so that they blocked direct access to the food. Because the webs were spiderless, the trapped bees could escape after several seconds of struggle. These bees often returned and would run the gauntlet again.

We found that bees reacted similarly to pigmented and unpigmented silks in dim light. They had difficulty seeing either web type because there was little light for the silk to reflect. In bright light, however, we found a marked difference in the bees' response to unpigmented webs and yellow webs. All the bees were caught in the unpigmented webs the first time they encountered them, but after escaping, they rarely ended up in the webs a second time. They learned quickly. Surprisingly, the bees seemed to have



A golden orb weaver tends to its web while waiting for a flower-seeking bee to be attracted to the yellow silk.
James H. Carmichael; Bruce Coleman, Inc.

trouble learning to fly around the yellow web, which was more visible. Many were caught more than once. We concluded that because yellow is a color common to many flowers that attract bees, it was actually attracting them to the webs. Perhaps the golden orb weaver's ability to adjust the reflectance of its silk to a variety of habitats enables it to feed on whatever insects are locally abundant, and therefore accounts for its exceptionally broad distribution.

Since bees are drawn even more strongly to violet flowers than to yellow ones, we wondered why some orb weavers didn't spin webs in violet or other floral colors. We trained additional groups of bees to forage at the sugar dishes and this time blocked their paths with webs tinted violet, blue, green, yellow, red, and white. We found that yellow webs caught more bees than any other, suggesting that the golden orb weaver has evolved to produce webs in the color that the bees have the most trouble learning to avoid. The bees, however, rapidly learned to avoid the violet web. Even though bees prefer violet flowers to yellow ones, this experiment suggests that bees can associate violet with danger as easily as they can with a nectar reward.

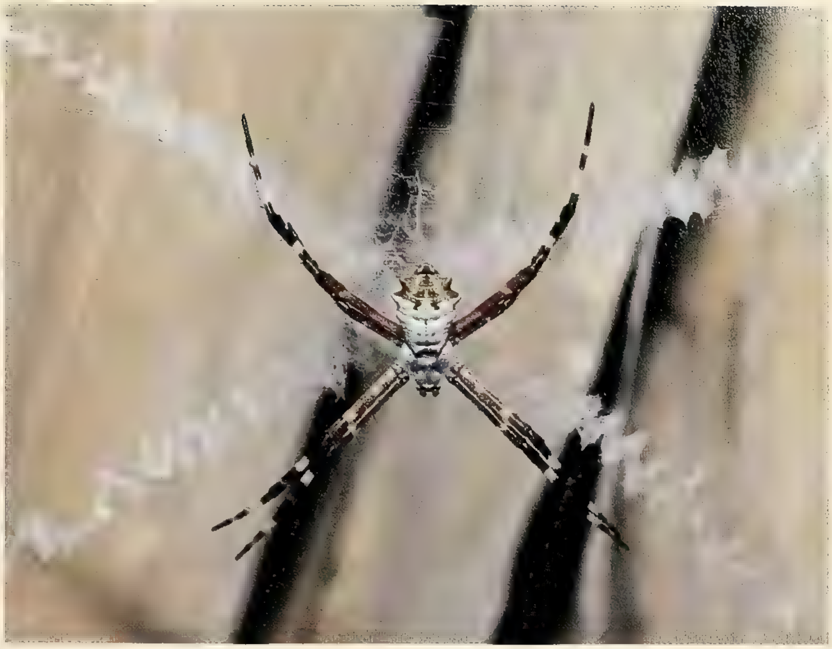
Our studies of another spider, *Argiope argentata,* a large orb-spinning spider often called the silver *Argiope* and distributed as broadly as the golden orb weaver, suggest that these spiders take advantage of an insect's ability to recognize patterns, as well as colors. Once an insect has been drawn to a flower by its bright color, contrasting stripes or chevrons on petals often guide it to the nectaries. Many such patterns reflect only in ultraviolet light and are therefore invisible to us, but most pollinating insects see them easily. Others have shown that honeybees can even discriminate between the different shapes and patterns, a faculty that helps them remember the location of flowers. We therefore wondered whether bees used this ability to avoid webs.

The silver *Argiope* uses nearly invisible silks, similar to the unpigmented silks of the golden orb weaver, but instead of building its web in the dimly lit forest understory, it spins webs in brightly lit sites where they are hard to see. One part of the web is conspicuous, however. The spider decorates the trap with bold, zigzag patterns that strongly reflect ultraviolet light. These patterns are usually located in the middle of the web and form a cross (although one or more arms may be missing). Each night the spiders spin a new web and produce a different silk design. Sometimes they will skip a day and leave the web undecorated.

To see what effect this had, we decided to decorate webs ourselves, using a variety of patterns we collected from other webs. We found that if we used the same pattern two days running, the number of insects caught the second day always dropped. But if we changed the orientation of the decoration from day to day—so that the patterns varied—the number of insects trapped each day remained constant. Apparently, the spider's innovations interfered with the bees' ability to learn and remember the web locations. We conducted further studies and found that if stingless bees learned to avoid one of our decorated webs at one site, this had no effect on their ability to avoid other webs that they encountered with identical zigzag patterns.

Many other orb-spinning spiders decorate their webs with patterns that vary from zigzag crosses and doilylike designs to horizontal bands and silk tufts dispersed throughout the orb or on the frame that supports the web. These patterns may communicate different kinds of information to insects with different foraging behaviors. For example, because the sky is the only natural source of ultraviolet light, UV-reflecting silk tufts may suggest open space to insects navigating through dense vegetation.

Regardless of the message that colorful webs and decorative silks communicate to insects, both the golden orb weaver and the silver *Argiope* have evolved hunting techniques that make use of the ways insects perceive and process visual information. As a result, insects may have difficulty evolving an effective defense against the orb spinners. If bees see the decorative silks spun by the silver *Argiope* as similar in color and shape to the grass flowers from which they gather pollen, they may find the webs difficult to avoid. If natural selection favored bees that learned to avoid the spider web patterns, then these bees would also avoid grass flowers and miss out on a valuable food source. The same goes for insects attracted to yellow flowers. Thus the need to use color and pattern to find food must outweigh the risk of being captured by a spider.



The brightly colored body of the silver Argiope *and the zigzag pattern of its web design attract insect prey. Because the spiders change the design daily, even bees that can recognize and remember patterns have trouble avoiding the web.*

Brian Kenney

Spider Revolutions

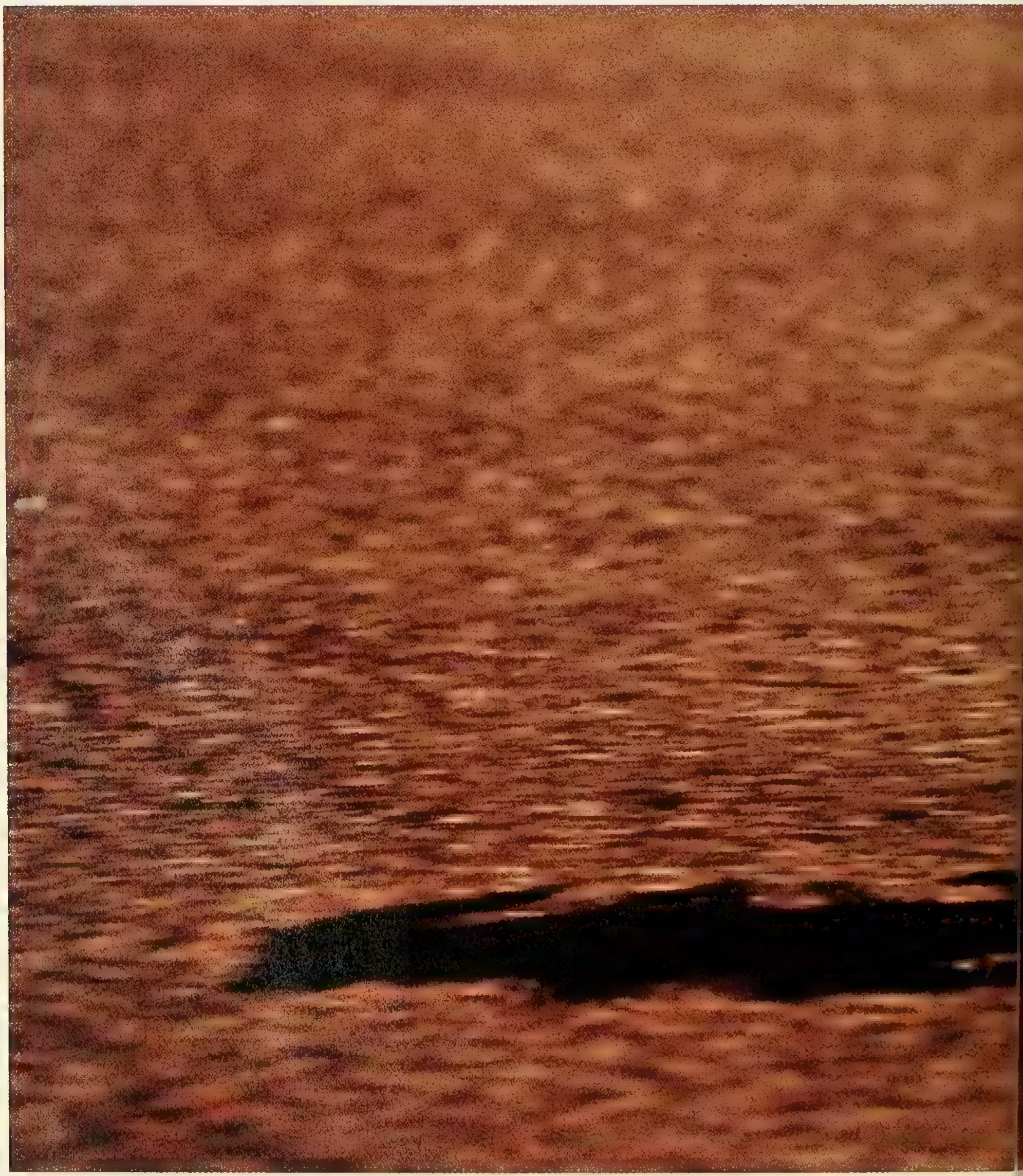
In the barren dunes of Africa's Namib Desert, one spider has invented the wheel

by Joh Henschel

A strobe of sky-blue alternating with dune-red flashes past the spider's eyes twenty times a second as it hurtles down a dune. With its eight legs neatly tucked in, so that one set of joints points outward to form a circle, the spider has become an upright wheel, rolling down the steep sand slope with tremendous speed. Near the top of the dune, its archenemy, a pompilid (or spider) wasp searches in vain for its quarry, which has suddenly disappeared.

In 1977, when David Hughes and Anthony Bannister first filmed the wheel spider's behavior in the Namib Desert of southern Africa, they postulated that it might allow the spider to escape attacking wasps. Wondering if predators could really be the impetus for the evolution of this unusual mode of travel, I decided to learn more about the spider.

Wheellike locomotion is rare in nature. Pangolins, hedgehogs, armadillos, and pill bugs may tumble downhill when they curl up into protective balls, but their spherical bodies roll without orientation and are thus not proper wheels. Snakes that take their tails in their mouths, becoming hoops, remain in the domain of myth, but looping stomatopods (small, shrimplike crustaceans found in intertidal zones) exist. They somersault backward when stranded, turning like bulldozer treads. Besides that, Namib dune



To make a quick getaway from sand dune predators, the wheel spider folds up its eight legs and goes into a downhill spin.

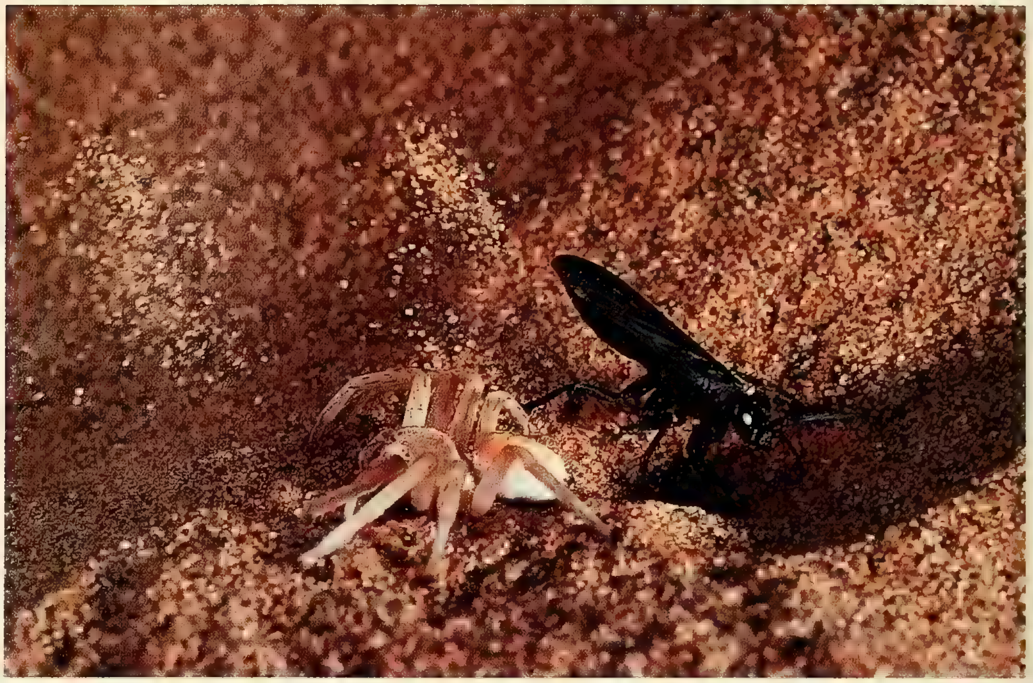
Photographs by Michael and Patricia Fogden

spiders are the only animals we know of—other than ourselves—that purposefully and readily use a planar wheel for locomotion.

Of course, wheels with axles are ruled out in multicellular animals because such a rotating organ would be severed from the body's nutrient supply. This limitation, however, does not rule out wheels without axles, like tires removed from a car. But wheels work best on roads. On natural terrains, soft ground yields under the weight of a rolling object, slowing it down. And obstacles greater than a wheel's radius would be absolute barriers.

One of the few natural places where wheels might roll freely is across open desert sand, especially if it is steeply sloping. With hundreds of square miles of regularly spaced, high dunes, the Namib Desert is an ideal place for an animal to have evolved this mode of travel. Weighing little, the wheel spider makes almost no impression on the sand, but its barely discernible tracks allowed me to measure the circumference of the wheel and calculate the number of revolutions and speed of the spider. With the help of gravity, the one-half inch spider can accelerate to speeds of 1.5 to 5 feet per second. The average of twenty revolutions per second that I measured for the spiders is the same as that for the wheel of a sedan traveling at 137 miles an hour. On slopes greater than fifteen degrees, the speed increases as the spider rolls. In the fastest rolls I measured, the spiders made forty-four revolutions per second. Large spiders turn more slowly, and heavy females carrying eggs in their abdomens are unbalanced and topple easily.

As its specific name *Carparachne aureoflava* suggests, the wheel spider is a beautiful golden yellow, although individuals may vary from white to bronze. To escape the scorching heat of the Namib Desert, the spider shelters in a burrow in the sand during the day and hunts for insects on the surface at night. To prevent the walls of its burrow from collapsing, the spider pushes its very long spigots—fingerlike projections at the



A female pompilid wasp digs a hole to bury a wheel spider that she has paralyzed with her sting. She will inject a single egg into the spider's body, which will provide live food for the wasp's developing offspring.

tip of the spinnerets—deep into the sand and binds the loose grains with silk. In this way, the spider can dig angled burrows more than a yard deep into a dune face and seal them shut with a trapdoor also fashioned from silk.

Depth provides safety from most enemies. On the surface, wheel spiders may occasionally encounter lizards, dune larks, large, voracious dancing white lady spiders, or cannibalistic neighbors of their own species. Wheel spiders can escape by dashing into their burrows, where only one predator seems to be able to extract them with ease: a palpimanid, or hook-footed, spider, will patiently sit on the trapdoor of a wheel spider burrow, dangling its enlarged front legs into the burrow. When the wheel spider tries to evict the palpimanid, the smaller intruder grabs the resident, killing and eating it on the spot. Neither the burrow nor wheeling protect the spider in this case. Fortunately for wheel spiders, their habitat contains few palpimanids.

Pompilid wasps are also specialized spider hunters, and they are more plentiful in the dune fields. (I found an average of about seven of these conspicuous black wasps per acre.) A female pompilid wasp captures a spider by first immobilizing it with her sting. She then buries the paralyzed spider temporarily, while she searches for a suitable place in stable sand to dig a long, narrow hole. She then returns to the spider, exhumes it, and drags it—often hundreds of feet—to the new hole. Placing the spider into the cool, slightly moist depths of the hole, the female lays a single egg in its body. When the parasitic wasp larva hatches a few days later, it will consume the still-living spider and go through all its life stages nourished by the tissues of its spider host.

When the wasp reaches adulthood, it emerges from its sandy tomb to mate and, in its turn, to hunt for more spiders. Capturing them, however, is no easy task. Female wasps spend 75 percent of their active time searching for wheel spiders. They meander over the bare sand, often stopping to scratch holes. Occasionally, they dig a pit, only to abandon it and move on; after a few minutes, they fly for some distance and resume their search elsewhere. Sometimes they imbibe flower nectar or grass sap from isolated clumps of vegetation to replenish their energy.

When a female pompilid wasp detects a spider burrow, she digs several tentative holes in the vicinity. Sometimes she enters the burrow, only to be kicked out by the spider. These initial explorations may provide the wasp with vital information on the spider's size, the depth of its retreat, and the exact position of the burrow within the sand. If the wasp embarks on the next stage of the hunt—extracting the spider—she will expend a lot of energy. The soft, unconsolidated sand in which the spider prefers to live collapses into the wasp's excavation, so that the hole widens out into a cone. The deeper the hole gets, the more work it involves. To dig a six-inch hole on a shallow slope, the wasp must move about ten pounds of sand, or 80,000 times its own weight. The wasp can do this, but no more. On steeper slopes, more sand slips into the hole than can be excavated. The steepest possible slope on loose sand is 33 degrees; at this angle, digging any hole becomes impossible, unless its walls are supported as they are in a silk-lined burrow. This is exactly the part of the dune the spiders choose for their burrows. Because of the instability of the sand, however, spider burrows sometimes collapse. When this happens, the spider builds a new, initially short burrow. Of the 114 burrows I examined, 5 percent were so short that the occupants were vulnerable to wasps.

If a spider is excavated by a wasp and is lucky enough to escape the predator's immediate sting, it has nowhere to hide on the bare surface. Fight or flight are its only options. The spider has an impressive threat display. It lifts itself high on its legs, raises some feet toward its opponent, and points its abdomen up. Then suddenly it drops low and shifts its legs. These alternating movements give the appearance of a curious dance. (The wheel spider's cousin, the dancing white lady spider, was named for its similar display.) If touched, the wheel spider instantly embraces and bites its foe. Although harmless to birds, lizards, or humans, the wheel spider's bite can be fatal to insects or other spiders. This strategy is useless against wasps, however; the wasp can simply avoid it by flying away or can counterattack with its sting. The spider's safest option is to flee.

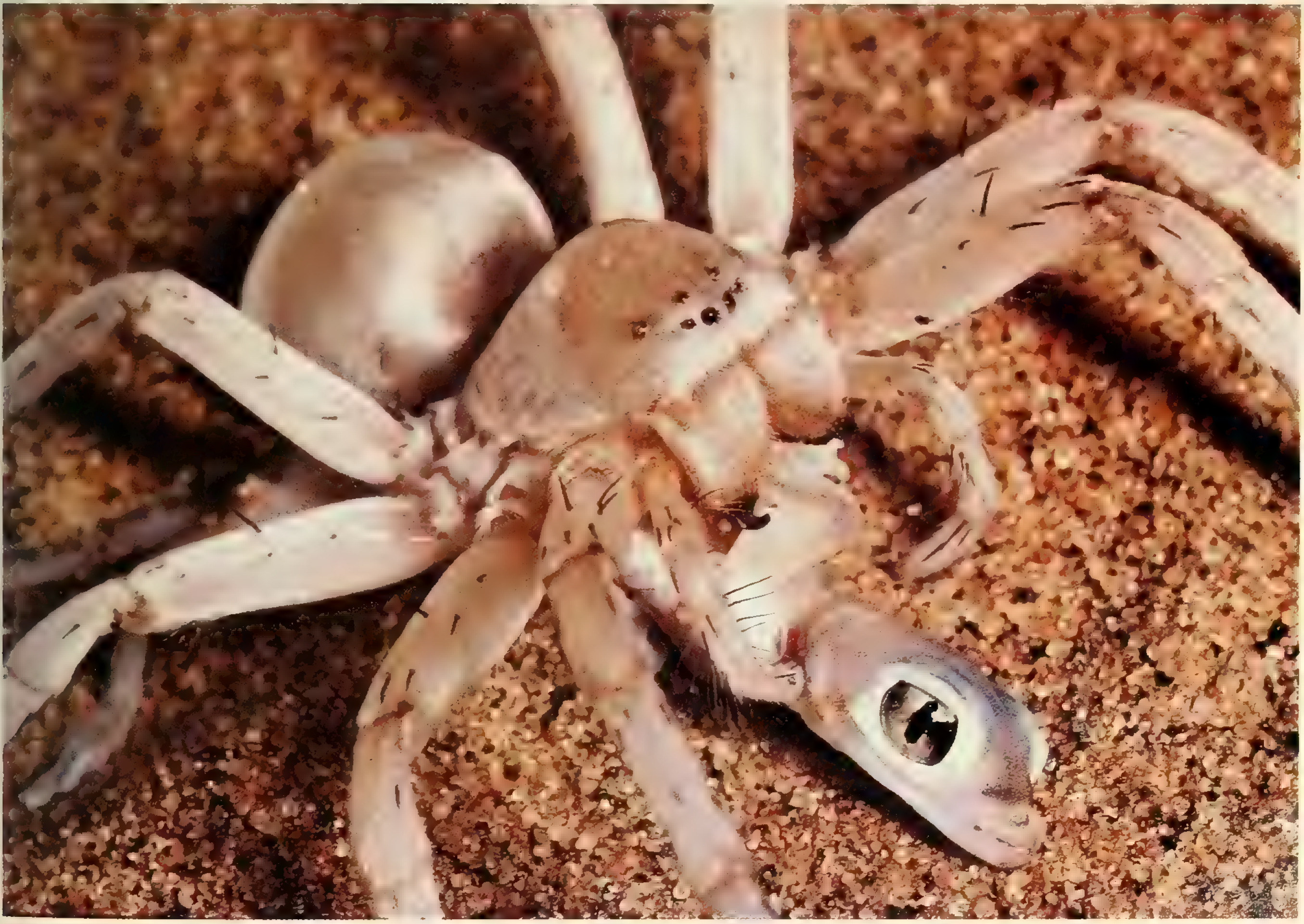
Wheel spiders can sprint, but not far. After running six feet in less than two seconds, they must stop to rest for several seconds before they can resume running. A minute is needed to cover thirty feet, and resting when its foe is so close by can be fatal. Resting, however, may be a necessity. Ken Prestwich, of the College of the Holy Cross in Worcester, Massachusetts, found that during vigorous exercise, wolf spiders rapidly deplete their supply of energy-transferring molecules (ATP) and then need to recuperate. Assuming that spider physiology doesn't vary greatly from one species to another, I can only infer that for wheel spiders, too, resting is essential.

For the wheel spider another disadvantage of running is the ease with which the wasp can follow it. Wasps can fly above their quarry or follow its trail on the ground, probably using their antennae to "smell" the trail. On a gentle slope, running may be the only way a wheel spider can try to flee from a wasp, but it is an inferior method of escape compared with wheeling on a steep slope.

When it wheels, the spider can maintain a high speed over a long distance without expending much energy, and the trail it leaves is too faint for the wasp to follow easily. The outline of the revolving spider disappears in a blur. Even though topography limits the direction and distance the wheel travels, I have never seen a wasp catch a spider that wheeled.

By living on a steep slope, the wheel spider is relatively safe in its burrow and can also escape effectively. Those that settle on shallow slopes to avoid territorial wheel spider neighbors, or that remain at the bottom of the slope after having wheeled, risk facing their most common and persistent enemy. The ingenious, specialized hunting method of the pompilid wasp may be the selective force that paced the evolution of the spider's revolutionary method of escape.

Their large size allows wheel spiders to ambush small vertebrates, such as this web-footed gecko, another common inhabitant of the Namib Desert's dunes.



Dancing in the Dome

Males are lured by food and sex into erotic contests and deadly brawls

by Paul J. Watson

The best time to see the webs of the Sierra dome spider at my Montana study site is just after a summer dawn, when the sun's rays stream at a low angle through the undergrowth. Within a 150-foot radius of my cabin at the Flathead Lake Biological Station, perhaps 300 female spiders spin their glistening dome webs between low, leafless branches. Webs are usually four to sixteen inches wide, with a characteristic dome structure one to three inches tall near their centers. Each day, the spiders clean, renovate, and enlarge their webs, giving meticulous care to the dome. The undersurface is their living space, where they annually reenact a silent, ancient drama of sex and combat.

My study site is on a small, forested peninsula that juts into an enormous glacial lake. The cool, shoreline location harbors a dense spider population, as well as swarms of insect prey, such as mayflies, caddis flies, gnats, midges and mosquitoes, that begin life in the lake and its many inflowing streams. For more than a decade I have come to this forest of ponderosa pine and Douglas fir, with its understory of honeysuckle, rose, and ninebark, to study the Sierra dome spider's intricate reproductive life.

At first glance, the female appears to lead an easy existence nestled within the relative security of her silken labyrinth, quietly waiting for prey and for wandering males to find and court her. But although she is visited by ten to twenty eager suitors over the course of the summer, she typically mates with only three or four. And of these, often only one male will sire the majority of her brood. Other males may share in fathering perhaps 20 to 30 percent of her offspring or none at all.

I wondered why females typically mate with several males, and how they select which will sire their offspring.

In September and October, the female spider produces a silken egg case, in which she lays 20 to 100 eggs, depending on how successful a forager she has been. Afterward, she binds the whole mass in silk. When the eggs hatch thirteen days later, the spiderlings, known as first instars, stay within the egg case. They soon molt to a second stage, but still remain in the silken case throughout the winter. When they finally emerge in March, juveniles of both sexes live solitarily for a time and seek out sites for their own domed webs. After growing through five or six additional molts, the spiders reach sexual maturity in late June. Most males mature within a two-week period early in the summer, as do some females, but not until mid-August will all females reach adulthood. Most males have died off by the end of the summer; the females commonly live into the autumn during their one-year life span.

Upon becoming sexually mature, the male's lifestyle changes completely. He abandons web building and begins to search for females on their webs. The males are not only looking for mates; they are also searching for food. Without a female's web in which to capture insects, the nomadic adult male has no way to eat.

From late in her final juvenile instar and throughout adulthood, a female Sierra dome spider can expect a new male to visit her web every two to three days. Such visits often last for eight to ten hours, and sometimes even as long as two to five days. Staying in the female's web enables

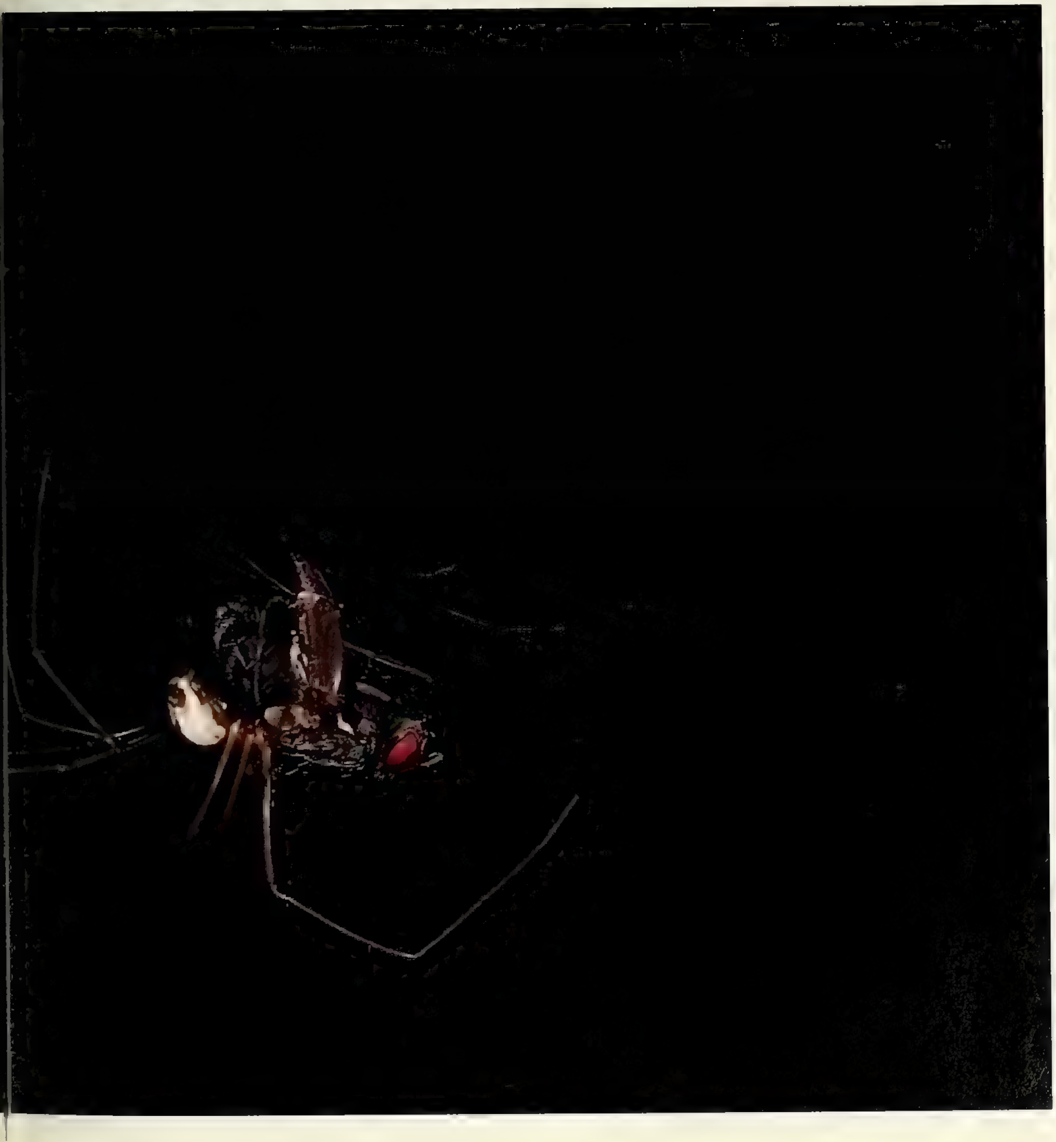
males to capture prey, find refuge from predators, and with effort and luck, copulate with the resident.

But such visits are problematic for a female. Her ability to reproduce depends on a rich diet, and a nutritious yolk must be provided for each of her eggs. Yet visiting males may gobble up three-quarters of all trapped prey. Unless a female arrives near a struggling insect well before the male, and the prey is small enough for her to carry off easily, the male will promptly grab and consume it himself. Whether they mate or not, males commonly linger to eat and enjoy the web's protection from such daytime predators as wasps and birds.

Although Sierra dome spider males are stronger, larger, and more aggressive than females, they are physically unable to force them to mate. A male's delicate pedipalps, which include the copulatory organs, consist of many bizarrely shaped plates joined by pliant tissues. If a female suddenly twists about or attempts to uncouple too quickly, the male organs can be damaged. Continuous, precise alignment between the male and female parts is necessary, as their genitalia have a close lock-and-key fit during copulation. During intromission, the male sits above the female with his fangs directed away from her, making it impossible for him to retaliate if she becomes uncooperative. Frequent copulating can increase the female's vulnerability to predators, even though her web provides a vibratory early warning system. If the pair is startled and shifts even slightly out of the mating posture, unlocking their sex organs can require nearly a minute—plenty of time for even the most cautious predator to seize them.

The vigor of a female's offspring is probably increased if she selects fit males as sires. From a genetic perspective, the more suitors that visit the female, the better her chances of meeting high-quality males. But how to judge male vigor? A female cannot test males by engaging them aggressively because all males can easily beat her. At the same time, she needs to address the problem of males stealing her prey.

One tactic for dealing with these issues is used by the female just before she becomes mature: pitting male suitors against each other. Females more than five days from maturation stringently



A large fly has blundered into a female dome spider's web, but a visiting male has beaten her to the prize. The female, at left, tentatively pokes the male for stealing her dinner, but stops short of attacking him.

Photographs by Paul Watson

avoid close contact with all males. Then, two to five days before reaching sexual maturity, she begins to advertise her upcoming final molt by staying close to any visiting male and allowing him to probe her body with his legs and pedipalps. If the young female avoids him, the male will depart within a few hours, leaving the female alone until the next male arrives. However, when a male finds a receptive young female, he attempts to win and maintain exclusive possession of her body and web until she matures. Guarding by the male is therefore constant. No male leaves the web of a receptive immature female unless he is forcibly kicked out by a rival. The resultant fights between males eventually lead to a well-tested "champion" on the web. This male becomes the female's first mating partner and usually fertilizes more eggs than any males that come after him.

This mate selection tactic requires many continuous days of male presence in the web; although this means heavy looting of the larder, it comes just at the time that is least damaging to the female's production of eggs. Female spiders normally fast just prior to molting, so the excess food consumed by guarding males during their several days of combat is less of a loss. How far in advance of sexual maturation and fasting a female begins advertising seems to depend on how well she is nourished; a longer period means that more food is sacrificed, but it also means that more males will have time to find the web and contend for her.

The timing of an immature female's receptive behavior seems to have evolved as a trade-off between foraging costs and the genetic gain of having many males vie for first mate status. After their first mating, females never again rely on fights between males to determine sires for their offspring. Perhaps the constant upkeep of a male guard is no longer affordable, as he uses up most of the available food.

Dome webs are supported by a network of fine threads that are difficult for a flying insect to see. When a fly or mosquito hits this superstructure at full speed, it falls, dazed, onto the dome. Alerted by the vibrations, a spider rushes over along the dome's underside, bites the prey, then pulls it through the web. Because the web is not sticky, the spider must seize the insect quickly or it will recover and escape.

Combat between males is not a fail-safe test for the best sire, however. If strong males happen not to show up during the young female's advertisement period, she may get merely the best of a bad lot. A web located near the edge of a population will draw fewer males. If the female matures late in the breeding season, most males may have already been killed in fights or by predators.

If combat between males is not an economical option, the female adopts an alternative method for selecting males with stamina, vigor, and physical coordination: she chooses the best copulator. A suite of adaptations allows her to separate the sex act from fertilization.

First, already mated females often attempt to persuade unwanted males to depart by a forceful, rhythmic web plucking that signals she is not interested in sex. If the female web-plucks, some males curtail their visits by two to three hours; others leave immediately. Still, many males persist; they may want the web's protection from predators or need food so badly that the female's sexual receptivity does not matter. Under these circumstances, however, a female makes copulation and courtship so demanding that the male is unable to compete with her for prey.

A male's pedipalps are not connected to the sperm-producing organs; he must first build a silk platform, or a sperm web, ejaculate onto it, and then draw the semen into his small copulatory appendages. When male Sierra dome spiders enter female webs, their pedipalps are empty. When a pair has been copulating for some time, the act is interrupted so that the male can fill his organs with sperm.

Although matings that eventually result in insemination may last two to seven hours, sperm is transferred only during the final thirty to forty minutes. Thus, most of the time spent mating consists of intromissions that cannot result in sperm transfer—hundreds of brief couplings performed continually over several hours. Each intromission is followed by withdrawal of the pedipalp, grooming it with the mouthparts, one to five seconds rest (a crucial area of variation among males); and then reinsertion of the same or the opposite pedipalp. Males strive to achieve high rates of coupling and uncoupling, and vary substantially in energy use during copulatory courtship. This summer we discovered that, in some males, the working metabolic rate could rise to seven times the resting rate. This is about as hard as a spider can work.

Both body size and intromission rate during copulatory courtship influence the fertilization success of secondary mates (those who become the second, third, or fourth mates of the female). The female chooses a sire for large body size, which my current research suggests predicts the brute strength and metabolic efficiency a male can pass on to his offspring. But she also chooses

those that demonstrate high copulatory vigor, which seems to be associated with their speed in summoning high energy for fighting or capturing difficult prey.

Copulation is consistently demanding for the male, but requires little activity of the female. Consequently, she can remain more alert to capture prey, which requires much quicker responses than the male can muster during mating. Since each intromission by the male lasts only two to three seconds, females can dash off to capture prey in the midst of copulation. While females take only 30 percent of the web's prey during other phases of courtship, during copulation they can grab as much as 80 percent. Females that do capture prey during mating seldom show any interest in resuming copulation until their meal is consumed.

Although more work is needed to be certain, dissections suggest that a female "chooses" which male sires her brood by opening or closing off her sperm-receiving ducts, thereby controlling fertilization of the eggs. How can we know whether females retain the sperm of one male or many, and which males end up being the sires of her brood?

I arrive at my study site with two assistants at the beginning of the summer, when all the spiders are immature. Then we select forty or fifty females on their webs and mark them. One of us visits every web every daylight hour for the entire summer. (The spiders do not mate at night.) We see all the males they mate with and monitor their foraging success hourly. Finally, we collect the successful males immediately after copulation, as well as the rejected suitors, and superfreeze them in liquid nitrogen. Eventually, we do the same with the female and her offspring.

In the laboratory, we analyze subtle, heritable variations in the structures of the spiders' metabolic enzymes, noting those that are unique to each individual. Using these biochemical markers, we can estimate the percentage of offspring that each male has sired. We can even tell how many different males have had their sperm utilized by the female, and which one she has chosen to be the principal sire of her brood.

In any sexual species, males and females must cooperate to reproduce. Much of the Sierra dome spiders' behavior, however, involves little cooperation and a good deal of conflict. Females set up a situation in which males compete with one another to perpetuate their genes and for their very lives—a contest it would be in their interest to avoid altogether. Females have evolved the equipment to dominate the ultimate decision as to which males will sire the spiderlings. And in their demand for long, arduous copulatory courtship, which simultaneously tests the male and reduces his ability to steal prey, the females have evolved an elegant solution to the dual problems of sire selection and foraging efficiency.

Two males, with their pedipalps extended, square off to do battle for an egg-laden female (topmost spider). Sexually mature females that remain unmated for a least a week will soak the web with a male-attracting chemical. In this case, the first male to enter the dome had begun to tear the web silk in an unsuccessful attempt to prevent other males from finding the female. She will have to repair the bunched silk at top right.

Samurai Spiders

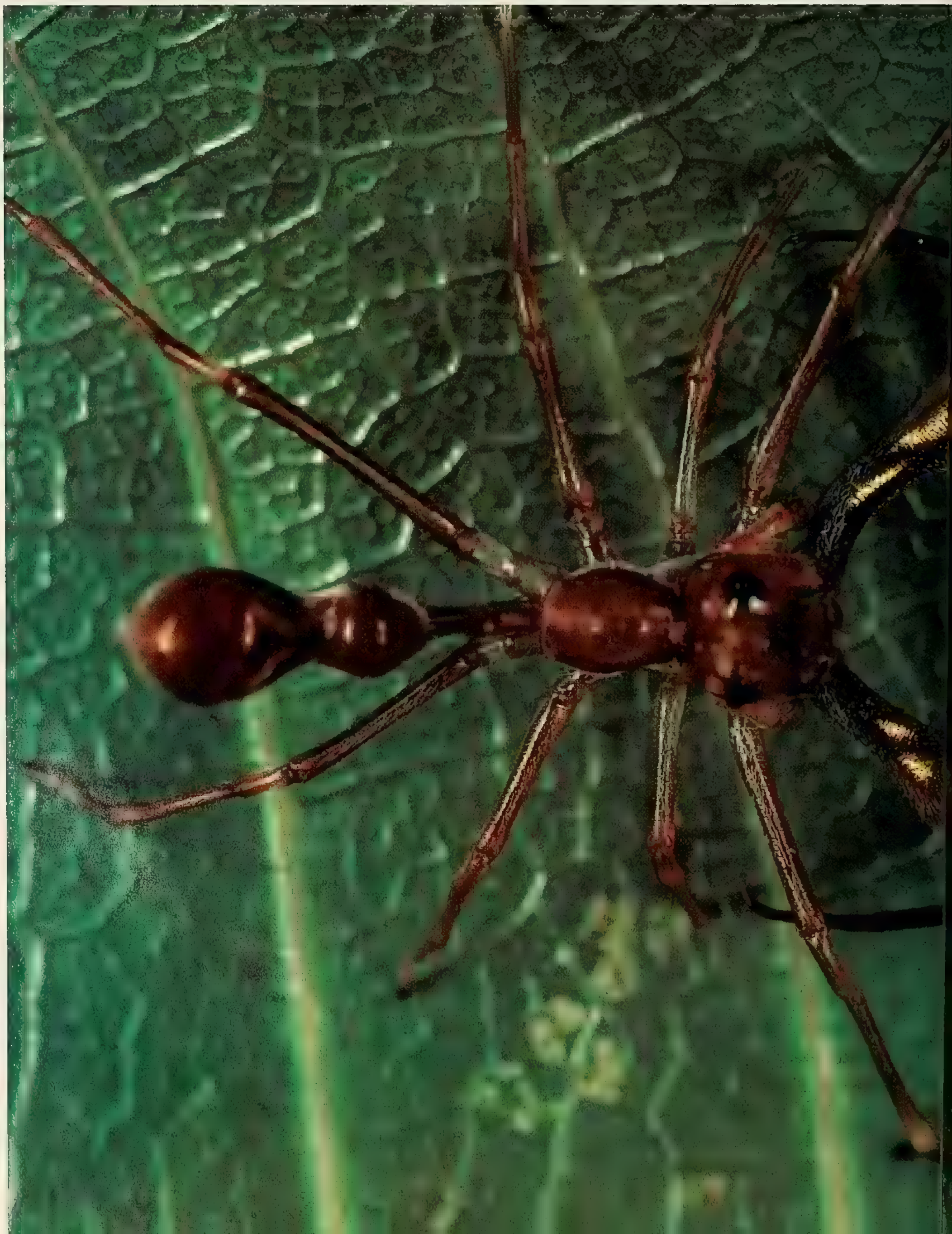
Male jumping spiders are always ready to do battle with rivals, but their "swords" make awkward weapons for killing prey

by Simon Pollard

Like knights from the Arthurian legend, two male jumping spiders maneuvering for battle unsheathe a pair of long swords and approach each other with fixed stares. The brief clash, which involves much pushing and shoving, is a contest of strength, most likely to gain a chance to mate with any nearby females. The swords, actually grossly exaggerated fangs, are kept crossed during much of the fight, and the battlefield is a rain forest leaf on the slopes of Mount Mikiling in the Philippines. After a few minutes, the smaller male backs away and runs off.

When the battle is over, the males retract the swords, folding them under so they are protected beneath their oversized chelicerae—the stout mouthparts that spiders use to grasp their prey while they feed. Like the medieval knight's clumsy weapons and heavy, protective armor, the spiders' elongated mouthparts appear to be quite a burden when not in use. Almost half the length of the spider's body, they seem to be handicaps to survival and, consequently, evolutionary enigmas analogous to the enormous antlers of the extinct Irish elk.

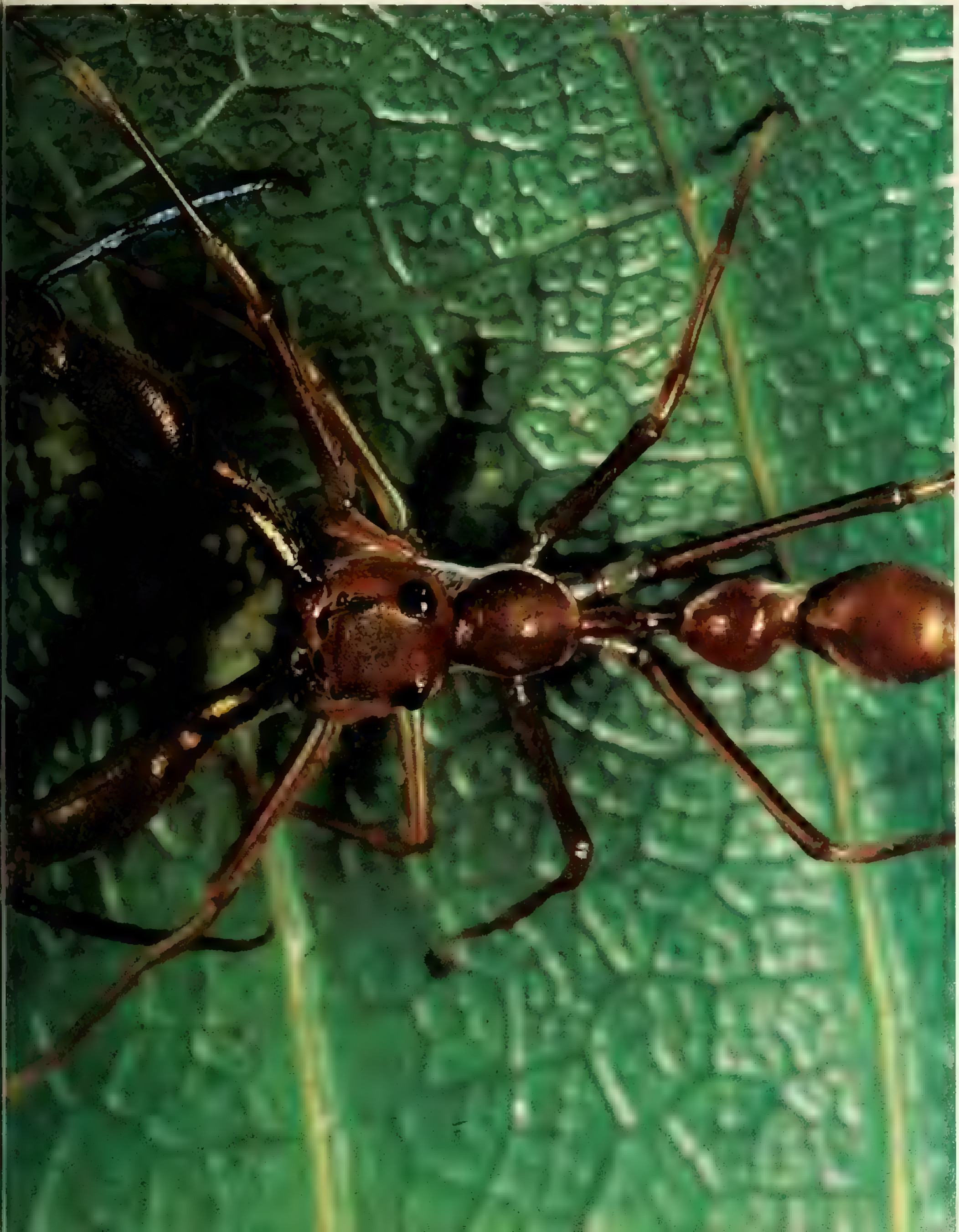
Similar male traits can be found in various



species throughout the animal kingdom and are usually exaggerated forms of structures found on females. Presumably, these ungainly structures have evolved because their costs are outweighed by the increased reproductive success that they bring. In the case of these spiders, *Myrmarachne plataleoides*, the large fangs have a practical function in battle and may also be more attractive to females selecting their mates on the basis of fang size.

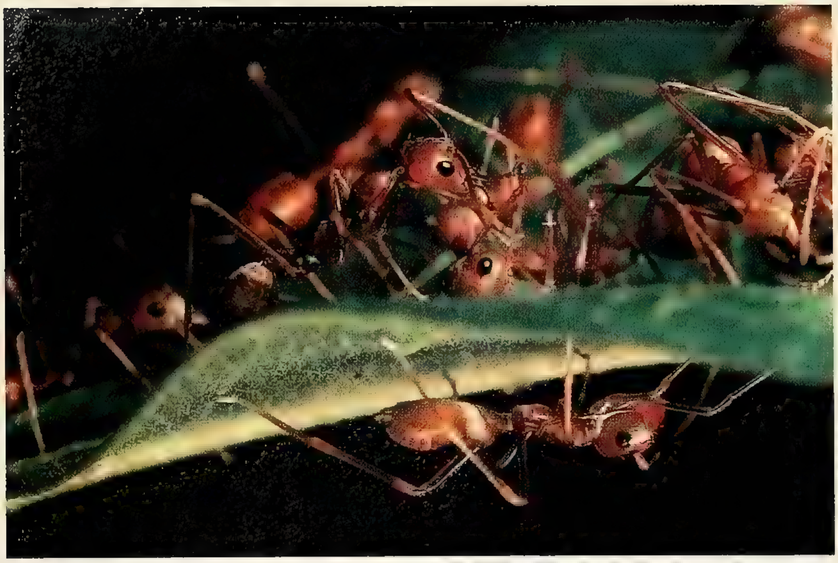
Jumping spiders, the largest family of spiders, have excellent eyesight and perform elaborate courtship and threat displays, often characterized by ritualized body postures and leg waving. Because they communicate mainly with visual cues in face-to-face encounters, it is not surprising that males evolved secondary sexual traits from mouthparts and other facial structures. Although a number of male jumping spiders have evolved horns and tusklike ornaments, those of male *M. plataleoides*, the diminutive knights on Mount Mikiling, are probably the most extreme of any spider known. For this reason, I decided to investigate what the costs might be of sporting these extraordinary weapons.

These spiders had already attracted considerable attention because both the males and females convincingly mimic weaver ants and are always found with ant colonies. With a couple of extra constrictions (in its cephalothorax and abdomen), *M. plataleoides* creates the illusion of having the head and pinched thorax of the weaver ant. The spider holds up its front pair of legs to simulate the ant's waving antennae, and two dark spots on the spider's sides mimic the weaver ant's large compound eyes. Only its behavior betrays this arachnid in ant's clothing. In a procession of ants traversing a plant, I pick out spiders by looking for antisocial "ants" that are facing opposite the flow of traffic. The spiders



In a battle for a nearby female, two male Myrmarachne plataleoides *wrestle with locked fangs. The spider with the largest fangs usually wins, but in this case they are closely matched, leaving the outcome uncertain.*

Simon Pollard



A convincing ant mimic, a solitary M. plataleoides *spider clings to the underside of a leaf swarming with weaver ants. This spider, either a female or juvenile, lacks the oversized fangs of adult males.*

Mark Moffett; Minden Pictures

carry pheromones, chemical compounds that trick the ants into thinking the interloper is one of them. Ants tend to ignore the spiders. The only benefit of the relationship goes to the spider, which has undoubtedly evolved its ant mimicry for protection; birds and other predators rarely eat ants because they bite, sting, and taste bad.

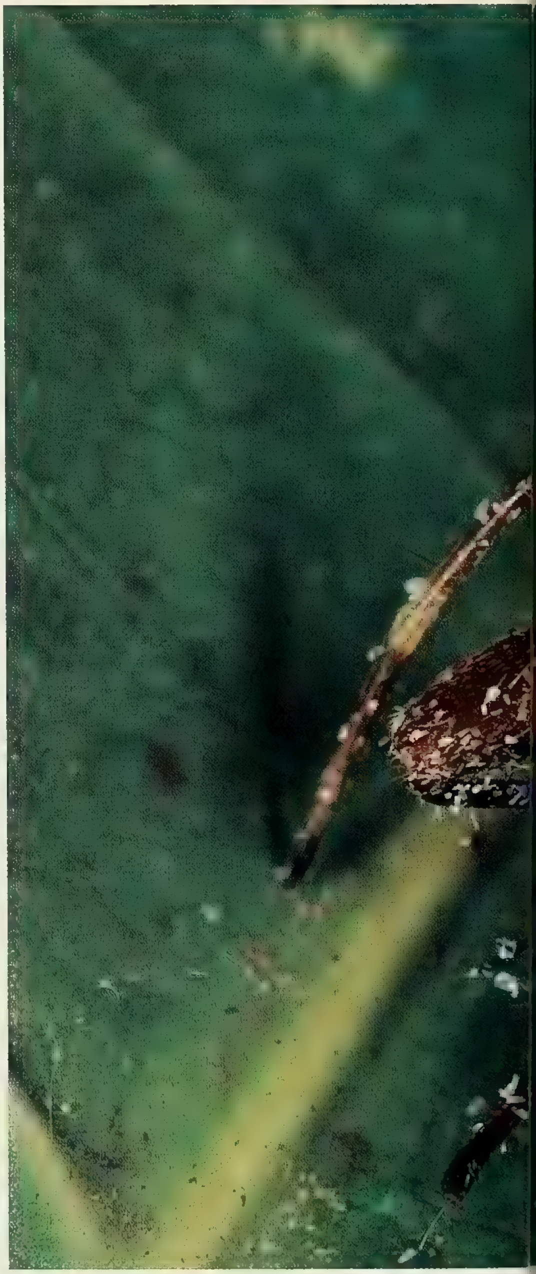
Immature male and female *M. plataleoides* are difficult to tell apart. But during the male's final molt, he undergoes a dramatic metamorphosis reminiscent of the special effects in a horror film in which a person's skull elongates and changes into that of a werewolf. The new chelicerae increase the spider's length by 50 to 70 percent, and they are rotated 90 degrees from the originals, so that the fangs open downward instead of to the sides.

At first, I wondered if this transformation might make the male spiders look less antlike. This question was largely answered when I reached down into a sea of ants and plucked out what I thought was a male *M. plataleoides,* complete with huge chelicerae. Upon closer examination, however, it turned out to be a weaver ant carrying a smaller worker in its mandibles. Weaver ant workers come in two sizes; large ones that forage for food and smaller ones that care for eggs and larvae inside the nest. Large workers commonly carry smaller nestmates between different parts of the extended colony. The spider's unusually large mouthparts therefore don't spoil its ant-mimicking illusion.

But a male's elongated fangs do prevent him from hunting in normal fashion and are a real handicap when he has to eat. When an adult male acquires his elongated fangs, he loses the ability to inject venom. The poison ducts become dysfunctional, ending long before they reach the fang tips. To reach all the way, the ducts would have to be about five times longer than those in females. At this length, the pressure produced by squeezing the venom glands (located behind the eyes) and the amount of venom would be insufficient to inject prey. It would be like having a very small syringe with a long needle. In comparison, when an adult female catches an insect, she unfolds her fangs, jabs them into the victim, and injects venom via a pair of ducts terminating at the fang tips. Once her prey has been immobilized by the toxins, she uses the fangs as can openers, to puncture and tear open her catch.

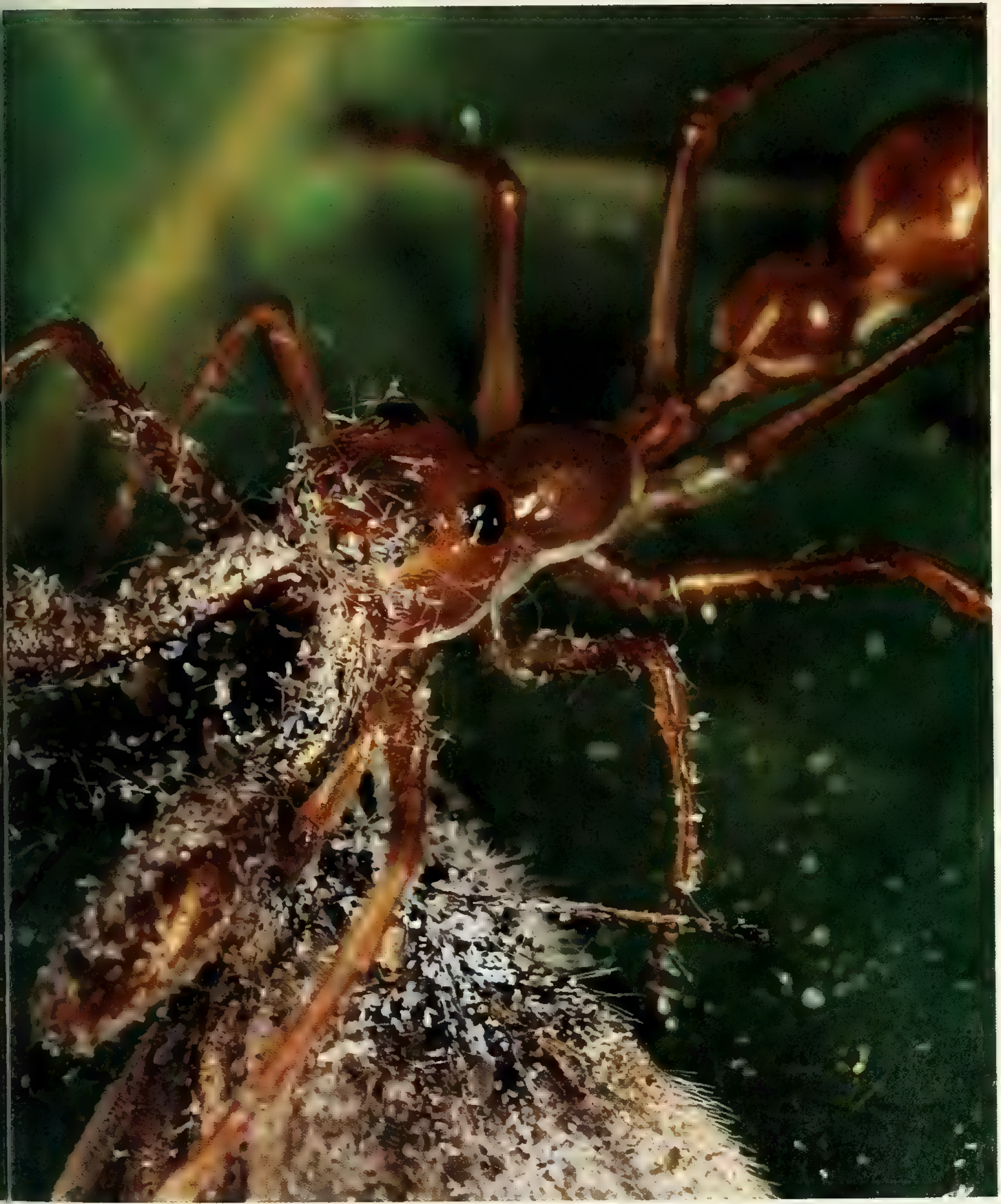
Consequently, males have to sit on their prey and stab it to death with their fangs—a technique far less effective than injecting venom. Arachnologist Robert Jackson, of the University of Canterbury in New Zealand, has observed that larger prey often escape from beneath these spiders. Males attempting to attack and subdue butterflies often look as though they have been tarred and feathered because they become covered in butterfly scales as they sit on the struggling insect and repeatedly stab at it.

Having subdued his prey, the male has the



added problem of consuming his meal with his ungainly weapons. A female feeds through the holes she has torn in her prey with her fangs. After liquefying the exposed tissues with digestive enzymes from her stomach, she sucks out the nutrients. Careful observations of males feeding in the laboratory revealed a much different technique. Because their fangs are so long, males have to push them through both sides of the prey's body so that the tips reemerge near the mouth. The male can then suck nutrients from the holes where their fangs have poked through. It's rather like drinking fruit juice from a carton by pushing a straw up through the bottom until it pokes out the top to make an opening. Not only do males take longer to feed compared with females, but because the prey is punched full of holes, much of the food is lost. After a meal, the male's fangs often resemble grisly shish-kebab skewers, with body parts of insects stuck along their length. I watched one male repeatedly wipe a fang against the ground in an attempt to remove the head of an unfortunate butterfly.

Because the males often live for several months after their final molt, the challenge posed by hunting in this awkward manner is significant. Unlike males of many spider species, which feed little upon reaching maturity, *M. plataleoides* males need the energy that prey provide to continue battling rivals and searching for mates. Nevertheless, sexual selection has produced a huge diversity of flamboyant structures and behaviors that allow males to outcompete rivals and impress females. While these often bizarre structures appear incongruous from a survival perspective, the reproductive benefits of having them outweigh their costs. And, presumably, that is why tiny male jumping spiders continue to jostle and wrestle with ungainly armaments.



Unable to inject venom, an adult male M. plataleoides *kills its prey by stabbing it repeatedly. Covered with scales after subduing a butterfly, this spider draws its victim to its mouth to feed—an awkward process for a creature with oversized fangs.*

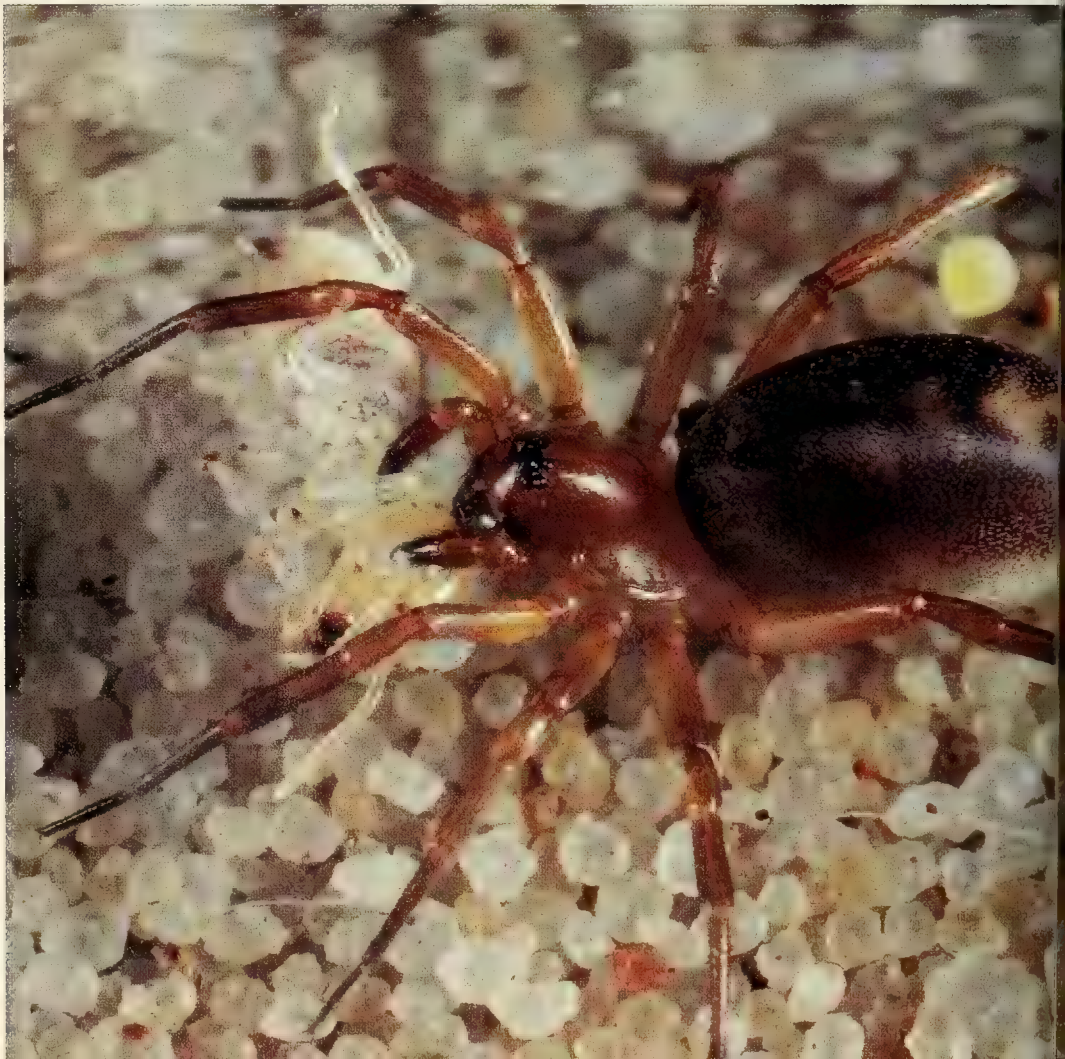
Simon Pollard

Tools of the Trade

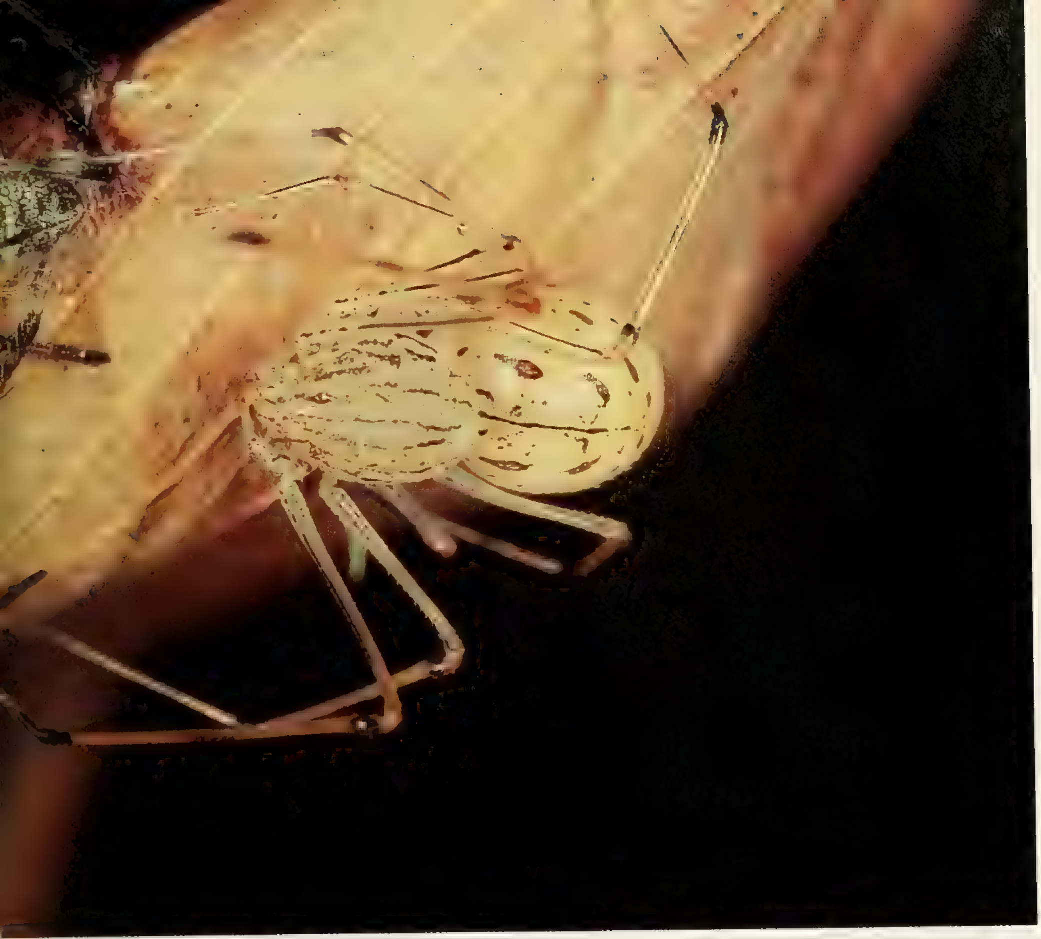
Spiders have evolved a few surprising ways to kill

Spiders have a remarkable array of adaptations for capturing and immobilizing prey. Many species secrete a liquid that imparts a stickiness to web silk. Others exude minute threads from a plate on their abdomen called the cribellum, rake these out with a special brush on their legs, and use the fibers to coat the much thicker threads of the web structure. Cribellar threads have a tacky property that insects can't easily escape and that scientists have never adequately explained.

The spitting spider of the genus *Scytodes* has a weapon that allows it to hunt away from its web. An enormous gland behind its eyes is divided into two compartments: one contains a toxin; the other, a gluey substance. The spider contracts the muscles surrounding the latter and a stream of glue is rapidly ejected from the animal's fangs. Sprayed out in a zigzag pattern, the adhesive



An African sand-dwelling spider, Diores termitophagus, *has approached its termite prey from behind and brushed it with front legs equipped with poison glands. After shivering and twitching for several minutes, the termite dies, and the spider begins to feed.*
L. Oates



Scytodes, *a spitting spider found in the Philippines, has ensnared another spider with a gluey substance sprayed from its fangs.*

Simon Pollard

forms a net that fixes prey to the leaf or twig it happens to be traversing. Robert Jackson, of the University of Canterbury, in New Zealand, and his graduate student Daiqin Li have been studying the behavior of *Scytodes* in the Philippines and have found that this formidable predator feeds primarily upon jumping spiders. When it encounters the devious *Portia*, however, it spits primarily in self-defense. *Portia* is one jumping spider that can draw close to *Scytodes* without being detected, and it routinely subdues and devours its spitting adversary.

A termite-eating spider with highly specialized equipment for paralyzing prey is *Diores termitophagus*, a southern African species recently described by Rudy Jocque, of Belgium's Royal Central African Museum, and Ansie Dippenaar-Schoeman, of the Plant Protection Institute in Pretoria. By day, this spider rests in an igloolike shelter it constructs from sand and pebbles; by night it hunts termites. Two glands just below its first knees contain a powerful toxin that is released upon contact with prey.

This chemical weapon is so important to *D. termitophagus* that it holds onto it even in the face of death. Unlike other spiders that, in their juvenile stages, can voluntarily "amputate" their legs to escape from predators, *D. termitophagus* sacrifices only the portion of the limb below the knee.—*R. A.*

An Abundance of Spiders!

After nearly 400 million years of evolution, spiders have conquered almost every habitat

by Norman Platnick

Wherever you sit as you read these lines, a spider is probably no more than a few yards away. Of all the organisms with which we share this planet, spiders are among the most diverse. Some 36,000 species, belonging to more than 3,000 genera and 105 families, have already been described. Even the most conservative estimates suggest that an equal number of species remain to be described. Thus, spider species probably outnumber all vertebrate species combined. In some parts of the world, as much as 80 percent of the spider fauna is unknown; only in northern Europe and the northeastern United States are the species relatively well cataloged.

Diversity aside, spiders are often the dominant nonvertebrate predators in fields and forests; even though they depend on insects for their prey, they can be astonishingly abundant. The late British arachnologist W. S. Bristowe estimated that a single acre of grassland in southern England, sampled during late summer, contained slightly more than 2.25 million individual spiders. That startling number may seem at odds with our ordinary perceptions, but the vast majority of those individuals are quite small, less than two millimeters (a tenth of an inch) long, and thus easily overlooked by casual observers. If all those individuals would combine the silk they spin in one day into a single, continuous thread, that line could circle the equator, and the silk spun in nine days would reach the moon.

Collecting the smaller spiders requires special techniques such as Berlese sampling, in which forest leaf litter and moss are sifted, and the concentrate is then spread out on screening over a funnel. Heat and rays from an electric light bulb suspended over the screen drive the spiders (and other soil organisms) through the screen and down the funnel, where they can be collected in a jar of alcohol at the funnel's tip. The seldom-seen spiders collected in Berlese samples are often so small that even a hundred specimens may fill less than a quarter inch in a small vial. Despite their tiny size, they perform an important role in soil ecosystems, consuming large quantities of springtails and mites.

The earliest fossil evidence we have of a spider comes from Middle Devonian rocks some 380-million-years old, found near Gilboa, New York. That fossil, a single spinneret from a spider's abdomen, complete with spigots at its tip, shows that silk spinning is at least that old. Abdominal spinnerets and their associated silk glands are unique to spiders; also unique is the presence in males of highly modified, complex structures on the pedipalps (the leglike structures near the mouth) that are used to transfer sperm to the female. The details of those complex palps, and the corresponding structures on the female abdomen that interlock with the pedipalps during mating, are the primary features used to distinguish one spider species from another.

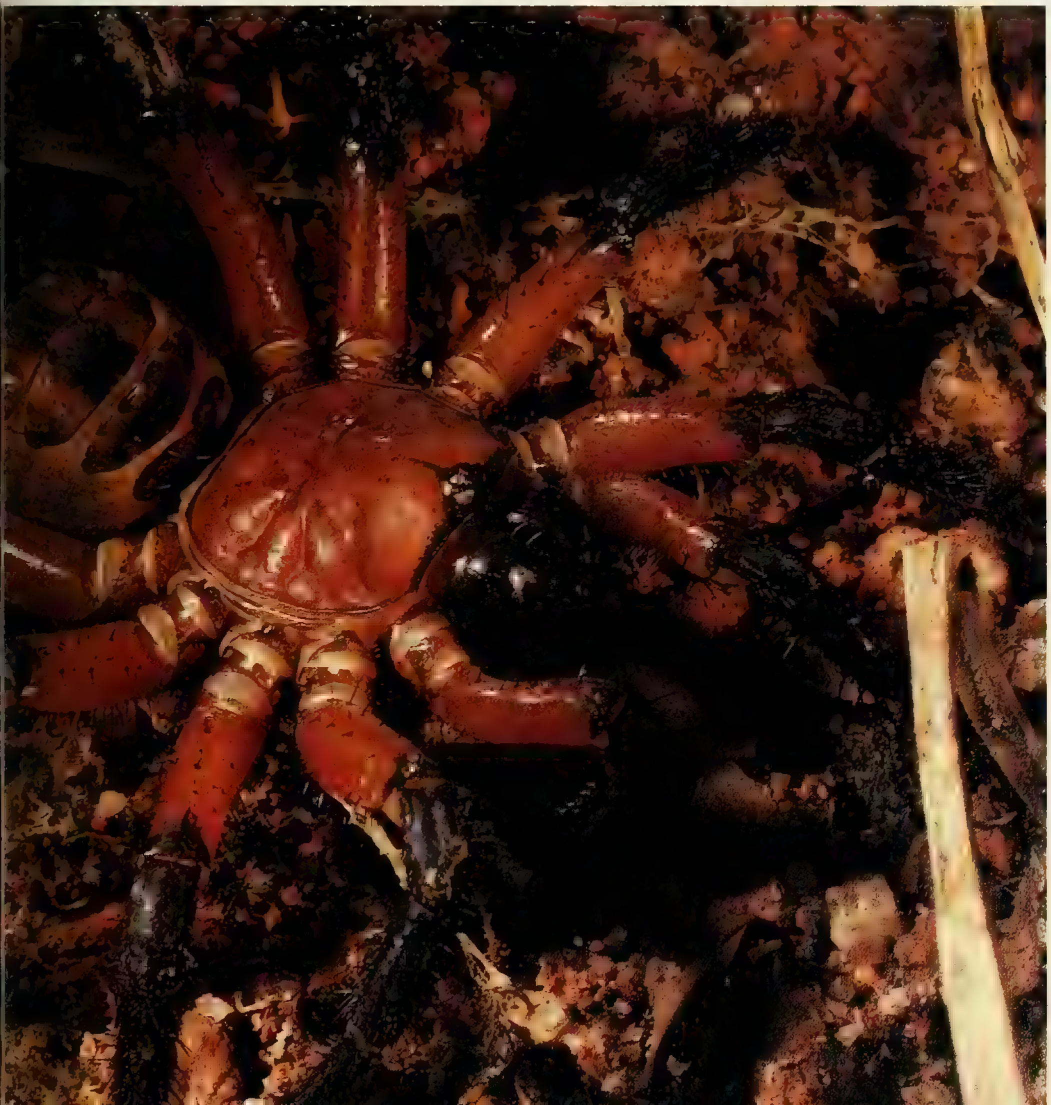
Since Devonian times, spiders have come to occupy almost all conceivable terrestrial habitats. On high mountains such as Everest, they have permanent populations living at an elevation of 22,000 feet, where they are the only predators in a community otherwise consisting of small flies and springtails that live on wind-blown vegetation. These spiders show no obvious anatomical adaptions to their extreme envi-

ronment, but are probably active only on sunny days (when temperatures on the rock surface can exceed those found at lower altitudes), spending the nights and cloudy days in silk cells spun under rocky debris (where they remain active even under the snow in winter).

Other spiders abound in the Arctic and, indeed, on all continents except Antarctica. Cave forms, which are often blind, unpigmented, and equipped with greatly elongated legs that increase the animal's sensing range in the dark, are common. Several species have invaded the intertidal zone, surviving daily submergence inside silk-lined retreats and feeding on the amphipod crustaceans common on beaches. Many species prey on the surface of freshwater ponds and streams, and one species in Europe even lives in freshwater, filling a silken "diving bell" with air bubbles brought down from the surface. Other species have become kleptoparasites, living and feeding on the webs of (usually much larger) host spiders.

During their long history, spiders have diversified into two suborders, which are differently represented in the modern fauna. One suborder, Mesothelae, contains only the forty-odd species of the family Liphistiidae, "living fossils" restricted to China, Japan, and Southeast Asia. Liphistiids are immediately distinguishable from other spiders by the series of plates covering the top of their abdomen, remnants of the body segmentation found in related animals such as scorpions. They also have features not found in more evolved groups of spiders, including a unique sensory system on their legs that allows them to keep track of their leg movements and provides our best clues to what the earliest spiders may have looked like. Liphistiids are burrowers that make silken trapdoors; in one genus, a series of up to eight "fishing lines" radiate out from the rim of the burrow. Passing insects trip over the lines, and resultant vibrations allow the spider to detect and locate its prey with great accuracy and speed.

All other spiders, Opisthothelae, are divided into two infraorders, mygalomorphs (tarantulas and their relatives) and araneomorphs ("true," or typical, spiders). The mygalomorphs comprise some 2,200 species of mostly large burrowers. Among the relatively few mygalomorphs found in the United States are the "purseweb" spiders, one of the most primitive mygalomorph groups. These animals spend their lives inside a silken tube, laid horizontally in leaf litter and often extending up the side of a tree. The outside surface of the tube is well camouflaged with bits of bark



A Malaysian liphistiid spider, with its distinctive segmented abdomen, is nearly indistinguishable from spiders of the Carboniferous period, 300 million years ago. This group of "living fossils" is limited to Asia.

J. A. L. Cooke; Oxford Scientific Films

and dirt. When an unsuspecting insect walks across the tube, the spider impales it with its fangs, cuts a slit in the tube, and drags the prey inside. Mygalomorph species generally have very small distribution ranges; a young trapdoor spider, when emerging from its mother's burrow, will often move only a few inches before starting to construct the burrow in which it will spend the rest of its life.

The most widely known mygalomorphs, of course, are the large, hairy tarantulas much favored by pet owners and Hollywood producers; their reputation as dangerous, however, is vastly overblown. Like almost all spiders, tarantulas do have venom, but in most cases the venom has little effect on humans (it has evolved, after all, primarily to be effective at subduing insects). Many New World tarantula species do have to be handled carefully, however, as they have urticating hairs on their abdomen. When disturbed, they use their hind legs to scrape the hairs into the air, and the barbs on these hairs can inflame skin and eyes. In nature, the hairs provide a defense against small rodents that might try to enter the spider's burrow.

The true spiders also comprise two lineages with very different representation in the modern fauna. One lineage consists of only the hypochilids, a primitive group of spiders represented by one species in China and ten in the United States. The other lineage contains all the other true spiders—more than 33,000 described species. The American hypochilids are called lampshade spiders because of the shape of the peculiar webs they construct under shaded rock overhangs. These webs are circular and much narrower at the top (where the spider hangs under the rock) than at the bottom. The species are widely disjunct: five are found in the Appalachian Mountains from southern West Virginia to northern Alabama, two in the southern Rocky Mountains, and three in California. Studies of their interrelationships by Kefyn Catley, a student working at the American Museum, indicate that the Rocky Mountain species are the most primitive members of the genus, and the Appalachian forms the most evolved. Catley surmises that the east–west disjunction within the hypochilids (which also occurs in some mygalomorphs, millipedes, and salamanders) dates back several million years to when deciduous forests disappeared from central North America. The small ranges and populations of some American hypochilids may imperil their future.

Such studies of the interrelationships of spider species often reveal correlations with past geological, geographical, and ecological changes that have affected the areas they occupy. For example, one ground spider subfamily contains just two genera, one in Eurasia and North America, the other in tropical America, Africa, and Australia. Studies of the relationships among their species indicated that the geographical separations between the genera, and among the species groups within them, generally correlate with continental-scale tectonic movements over the past 180 million years. The southern genus apparently diverged from the northern one when the Pangaean supercontinent was divided into Laurasia (modern Eurasia and North America) and Gondwanaland (modern Africa, India, Australia, South America, and Antarctica). The studies generated a prediction that the southern genus should be found in India, even though no specimens were then known from that subcontinent; the prediction was later confirmed, and three species have since been described from India. One implication is that some spider species may be as much as 80 million years old!

Their lengthy history and small ranges mean that spider species are potentially very useful, both for setting conservation priorities and for "bioprospecting." For example, to a forest manager in Chile faced with the problem of deciding which forest areas can be logged and which should be protected, the most informative group of organisms will be the one that has the largest number of different species restricted to separate areas within Chile. Preliminary indications are that spiders may be among the most informative organisms available. Some groups, for example, have fifty or more different species (mostly still undescribed) found only in certain parts of the country.

Because each species can have different venom and silk, the potential economic value of one of those species may be large. Spider venoms are increasingly being used in neurological research (primarily as blockers of nerve impulse transmission across synapses), and spider silks are actively being investigated by scientists interested in synthesizing fabrics that are as lightweight and strong as spider silk (which has a greater tensile strength than steel threads of the same size). Such synthetics could be used to make parachutes and bulletproof clothing. Most important, of course, is that without spiders to help check the growth of insect pest populations, we might have little left to eat. Bristowe estimated that the weight of insects consumed by spiders annually in Britain exceeds the weight of the human inhabitants! Spiders are used to help control insect pests in some crop fields, such as rice paddies, but most spiders will consume anything they can capture and are therefore not ideal for controlling specific pests.

With their high local abundance and diversity, spiders provide an endless source of fascination. The next time you see a spider, whether a dull-colored cobweb builder or a brightly patterned jumping spider, don't kill it—watch it, for you may find that its web-building behavior, its prey-capturing techniques, or its courtship antics offer a compelling glimpse of a seldom-seen world.

Highlighted by a heavy morning dew, orb webs hint at the number of spiders hunting in this patch of the Florida Everglades.

Robert P. Carr; Bruce Coleman, Inc.

Decorations adorn a camel in northwest India.
John Elk

Camels in the Land of Kings

The Raikas of India, traditional suppliers of camels, find their herds are dwindling

by Ilse Köhler-Rollefson

In February, against a backdrop of several hundred camels spread out to graze, five turbaned men huddle beside an impromptu campfire. Passing around a clay pipe, they discuss the outcome of the previous fair in Pushkar, the west Indian town where each November they sell their annual crop of young male camels. Even the batch of fluffy baby camels playfully darting around does not distract the men from their gloomy thoughts. One, a younger man named Gautamji, finally summarizes their predicament for me:

> Look at us. Only fifty years ago we had 10,000 camels—so many that we never even cared when we lost one in the jungle. Twenty years ago, there were 5,000. Now, only about 1,000 camels belong to our village. Ten years from now, or even sooner, we will have no more camels.

The men are Raikas, members of a Hindu caste that specializes in breeding livestock. While they also keep sheep, goats, and cattle, the Raikas are renowned as experts in camel breeding. Inhabitants of the state of Rajasthan, "the land of kings," many of them take pride in their centuries-old heritage as caretakers of the camel breeding herds that the local maharajahs once maintained to insure a supply of the animals for warfare.

Rajasthan's bleak landscape is dotted with forts and palaces that testify to past glory and heroism. Before independence, the region, which includes the harsh Thar Desert in the west, comprised several kingdoms. The rulers, who belonged to the Rajput warrior caste, were known for their courage, preferring death to defeat. Perpetually involved in internecine battles between their desert kingdoms or in repelling invading Muslim forces, the maharajahs used camel corps and relied on batteries of pack camels to provide logistical support in their arid territories.

The Raikas were one of many castes that provided specialized services to the Rajputs in exchange for their protection. When India gained independence in 1947, the feudal system was dissolved, and most of the royal camels became the property of the Raikas. The military uses for camels have dwindled over the years, but India's security forces still use them to patrol the boundary with Pakistan. Fortunately for the Raikas, however, a new purpose for camels developed: they came to play a crucial economic role as draft power.

In the past forty years, the camel cart has quietly revolutionized transportation in many parts of western India, notably in the states of Rajasthan and Gujarat. Modeled on the oxcart, the camel cart is considerably larger and equipped with used airplane tires that enable it to go anywhere, regardless of the condition, or even the presence, of roads. Ownership of a camel and cart for hauling loads provides a decent livelihood for thousands of people. In India's arid west, camels represent an indispensable source of energy that saves the cost of imported fuel.

The market for camels is still going strong, but the Raikas, who are the main suppliers of camels to farmers and small-scale transport entrepreneurs, are pessimistic about the future. The reason is simple. As traditionally practiced, camel

breeding relies on access to large expanses of open, often communally owned land—once amply available for grazing under the formal control of village councils. Within the span of this century, however, Rajasthan has witnessed phenomenal population growth, with the Thar Desert now deemed the most densely populated desert in the world. The consequent expansion and intensification of crop cultivation is one of the factors responsible for eliminating pastureland. Furthermore, some of the Raikas' traditional summer pastures in the Aravalli Hills, east of the desert, have been listed as nature reserves, and access to them has been drastically curbed. Although partly denuded of its dense vegetation, this ancient range still harbors considerable wildlife, including wolves, jackals, and a few tigers.

With grazing land scarce, the majority of the Raika camels are now teetering on the brink of starvation, and their chronic hunger has resulted in a drop in their fertility. Under optimal circumstances, camels are slow reproducers, a female giving birth to one calf every two years. The Raikas traditionally sell off only the male calves, keeping the female calves to replenish the breeding stock, which they regard as an ancestral legacy. At best, therefore, they can hope to have one male calf to sell per year for every four breeding females. But now the situation is far worse, for many of the females experience a delay in sexual maturity, suffer abortions, or die. Reluctantly departing from custom, the Raikas are now also selling off some of the females. These factors, combined with the loss of animals due to disease, have led to a drastic drop in camel holdings.

In addition to their economic woes, the

Brian A. Vikander

Ilse Köhler-Rollefson

Owners display their camels, left, at the annual fair in Pushkar, bottom left, where camels are bought and sold. Below: Vendors exhibit camel harnesses and decorations at Pushkar.

John Elk

Raikas complain that while they were once respected members of the larger community, they are now harassed whenever they show up with their herds. They are bullied by forest officials and even driven away by landowners, who once welcomed them with gifts of food and tea for the fertilizing manure the camels left on the fields.

Having studied camel pastoralists in other countries, I have always been struck by the limited way in which the Raikas use their camels. These self-imposed restrictions make it difficult for them to see a way of solving their current dilemma. To begin with, they follow an absolute taboo against the slaughtering of camels and the consumption of their meat, something that, to my knowledge, does not exist among any other camel pastoralists. When, at a recent conference that dealt with their problems, the Raikas learned that camels are a popular source of meat in parts of the Arab world, they sought, unsucessfully, an immediate ban on the export of camels to those countries.

This uncompromising attitude may have rubbed off from the taboo regarding cows in the Raikas' Hindu religion. The local Muslim groups take the same stance, however, although they may be less adamant about it. "The camel is our best friend—why should we kill it?" one Muslim commented. Since most of India's Muslims converted to Islam only in recent centuries, this attitude may be a holdover from their Hindu heritage.

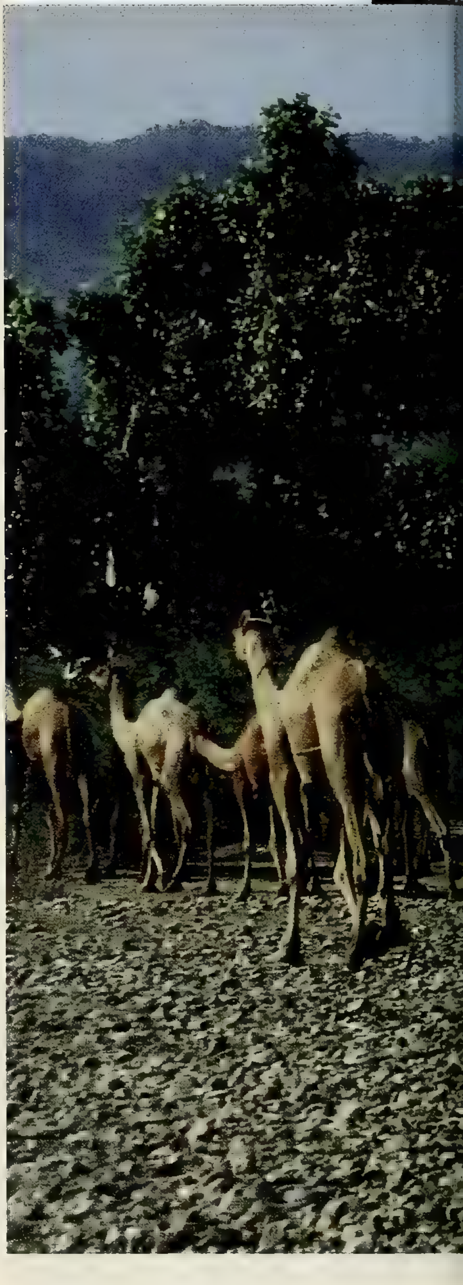
In addition, the Raikas are nowhere near exploiting their herds' potentials for milk production. For African camel pastoralists, camel milk is often a staple. But the Raikas milk their camels only sporadically. This has to do partly with the social organization of herding. Unlike other camel pastoralists, who travel as a group, following a nomadic lifestyle and living in tents or other mobile dwellings, the Raikas reside in colonies at the outskirts of villages. Women, children, and older men stay year-round in permanent houses. Only some of the able-bodied men accompany the herds on migration, when they need to search for pasture.

Often traveling more than 100 miles, the herdsmen take no cooking equipment with them—their entire gear consists of a blanket, a rope, and a clay container used as a milking vessel. Often they subsist almost exclusively on camel milk for weeks. But because a herd of 100 animals can be managed by about four men, only a few of the camels need to be milked.

Ilse Köhler-Rollefson

India's Border Security Force, below, uses camels to patrol the Thar Desert, which overlaps the boundary with Pakistan. A camel herd passes before the Aravalli Hills, right, a traditional grazing area that is now mostly a nature reserve. Raikas camp with their camels and goats, bottom right.

Doranne Jacobson



While it is common practice among other camel-oriented cultures to sour camel milk, the Raikas maintain that milk must be drunk fresh without heating, and they refer to various gods and saints who prohibited the manufacture of curd from camel milk. Thus they take no advantage of the possibilites for processing camel milk into longer-lasting products such as cheese or ghee (clarified butter). Occasionally, however, they make kir (rice pudding) or condense the milk of newly lactating camels into an invigorating tonic.

Milking, other than for immediate consumption, is also discouraged by a Raika caste rule that the milk of their animals should not be sold. The feeling is that one should not profit from milk, and that excess milk should be given to the needy. "Selling milk is like selling your children," I was once told by a Raika elder.

Utilization of the products of the dead animal, such as leather and bones, is also taboo for the Raikas and left to members of lower castes. The Raikas do shear their camels for wool on the occasion of the annual festival that marks the transition from the cold to the hot season. The wool is spun by the men and then handed over to a caste of weavers and leatherworkers, who weave it into blankets.

The restrictions the Raikas place on their use of camels should not be regarded as inherently irrational. The taboos once served the Raikas well, given that the herders' express purpose was producing the maximum number of transport animals. Exploiting camels for milk would probably have resulted in longer birth intervals and a higher mortality rate in the young camels. But the traditional taboos may now prevent the Raikas from adapting to changing circumstances.

Shedding old views will be difficult, however. For the Raikas, camels represent more than utilitarian objects. The group's association with this animal is an essential part of Raika identity. According to their mythology, Lord Shiva, one of the three principal manifestations of God in the Hindu pantheon, created the Raikas expressly to look after camels. I have many times listened to renderings of the touching story in which Parvati, Lord Shiva's wife, playfully shaped the first camel from a lump of clay. She then beseeched Shiva to breathe life into her toy, but the living camel proceeded to cause a lot of trouble. Implored by Parvati to stop the nuisance, Shiva then created the first Raika from a piece of his own skin and his sweat.

The camel is also an essential component of a Raika wedding. The bride's dowry includes a number of female camels given to the groom's family. And the bridegroom sits on a camel during critical parts of the marriage ceremony and, from the animal's back, touches the wooden arch erected for the occasion.

The strong emotional attachment of the Raikas to their camels is matched by the depth of their traditional knowledge about all aspects of camel breeding and management. As is the prerequisite for all pastoralists, the Raikas are intimately familiar with the terrain, the seasonal availability of pasture, and the properties of forage plants. Although the herdsmen are illiterate, they keep careful mental notes of their camels' pedigrees and can recite the ancestry and life history of each individual animal they own. They conceptualize their breeding stock as representatives of certain female bloodlines known for particular qualities. Stud camels are carefully selected for desired traits, including the

performance of their female relatives. To avoid inbreeding, the stud camels are changed every four years.

For observers from a Western culture, in which farm animals are often regarded as unpredictable and are restrained accordingly, the way the Raikas supervise and control the movements of hundreds of camels without any visible effort is particularly impressive. Much is done by voice, and a simple command can suffice to separate mothers and young into two different groups. The Raikas distinguish their female animals less in terms of milk yield and more in terms of easy milking. In the case of some camels, anybody can just walk up and milk them, while others have a close relationship to a particular herder and can be easily milked only by him. Many will not yield their milk unless their young are nearby, but some will comply when talked to in a sweet voice.

Ilse Köhler-Rollefson

Robert Frerck

A camel cart with rubber tires, below, is used to transport goods. The need for draft animals currently creates the main demand for camels in northwest India. Opposite page: An ornately shaved camel sits in front of the carved stone palace at Jaisalmer. The palace is a reminder of the region's royal past, when maharajahs vied for political control.

Ilse Köhler-Rollefson

asian paints

Another important component of the Raikas' indigenous knowledge is animal health maintenance. The Raikas distinguish a long list of diseases for which they have an array of treatments. The scourge of camel breeding is trypanosomiasis, a parasitic blood disease that resembles human malaria. Transmitted by biting flies, it is prevalent especially in years with above-average rainfall. The Raikas can diagnose it from the smell of the camel's urine—a method that has been deemed equivalent in accuracy to examining a blood smear under the microscope. Unfortunately, while the Raikas have several treatments for this disease, none of them cure it, and modern therapeutics are beyond their financial means.

For camel pox, which afflicts mainly young animals, the Raikas have developed a simple, effective vaccination. They take a sample of the blistered skin from an infected animal, mix it with water, and then rub it into shallow incisions in the nose of the animal to be protected. For chronic diseases, Raika animal healers resort to "firing"—they apply a heated iron to prescribed or affected areas. Firing is an accepted practice in Western veterinary medicine, especially with horses, because it is thought to increase blood circulation and thus promote healing.

The Raikas' large body of traditional knowledge and their aptitude in handling and managing camels are invaluable assets, yet these will be doomed to oblivion if camel breeding becomes an obsolete occupation. How can the Raikas adapt to the decrease in pastureland? With more investment, particularly in terms of better veterinary care and provision of fodder, the productivity of the herds could be increased. But such inputs are expensive and seem beyond the relatively meager incomes that can be made from selling male camels.

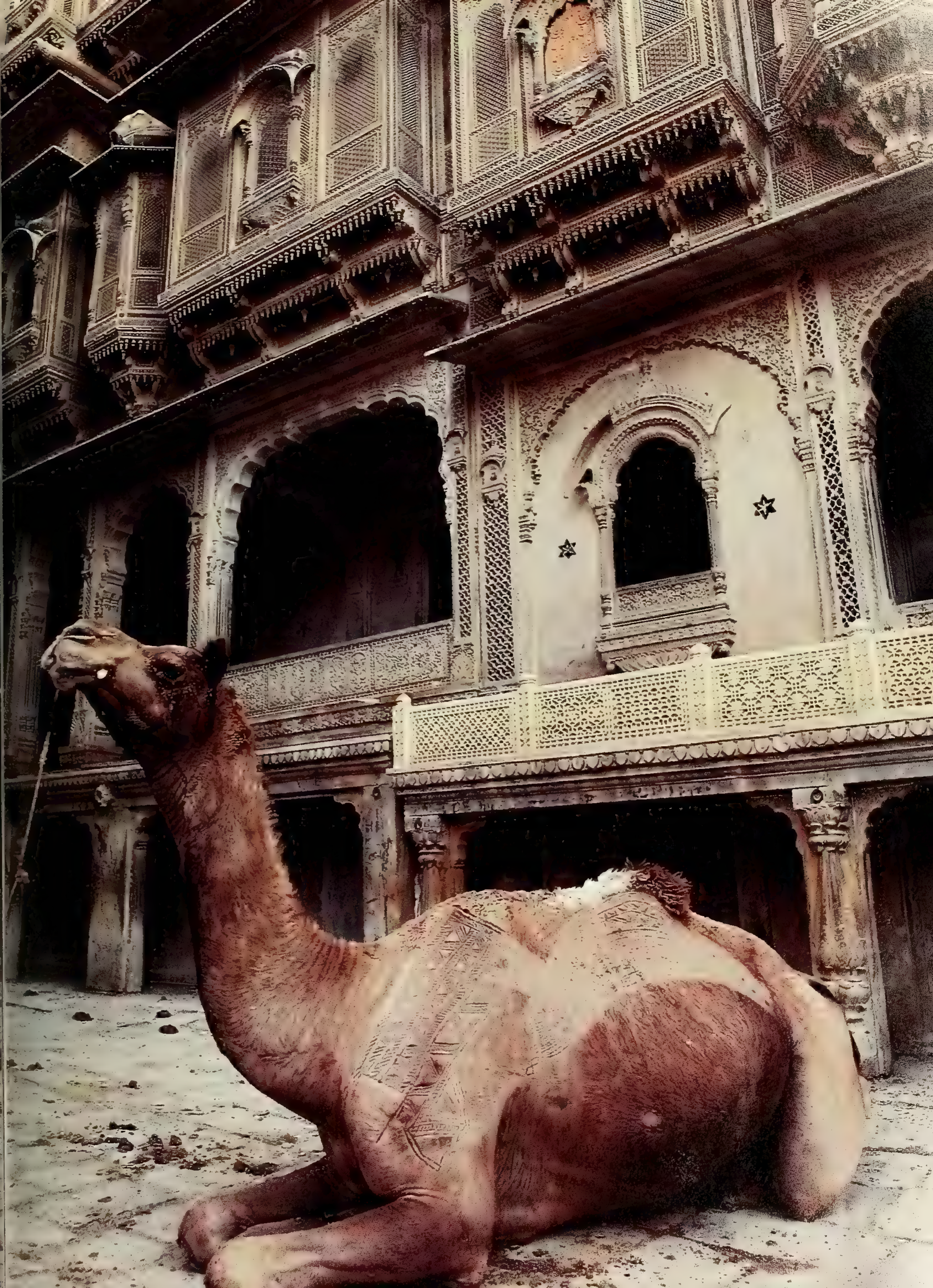
Because the Raikas have placed so many cultural restrictions on camel utilization, I was not particularly optimistic that they would find a solution to their quandary. I could not expect them to break with their traditions and slaughter unproductive animals or commercialize milk production. Yet sometimes—and especially in India—extraordinary things happen. Not long ago, my field assistant, Ruparam Raika, heard rumors about camel milk being sold in some remote areas of southern Rajasthan and the adjoining state of Madhya Pradesh. Soon after, Ruparam and I, along with my long-time interpreter and adopted brother, Hanwant Singh, made a trip to the area in question and discovered a thriving camel milk market.

The market had its beginnings about twenty years ago when some Rebaris—members of a caste closely related to the Raikas—started selling milk from a few of their camels to the owners of tea stalls. Their desperate attempt to break out of poverty paid off. They established extensive customer networks and expanded their herds accordingly and still could not supply enough milk to fulfill the demand.

In India, milk is an essential ingredient of tea, but also in the Rebaris' favor were the advantages of their product over the competition. The numerous tea shops generally have no refrigeration, and because camel milk can be kept longer without going sour, it wins out over cow and buffalo milk. It is also cheaper. Fear for their market share even induced some cow and buffalo milk sellers to stage a protest and strike against camel milk, charging that it was a human health hazard. In line with scientific findings, however, a number of local authorities supported camel milk as being of good nutritional value.

As news filtered back to the Raikas of the handsome profits being made from camel milk sales, they did not take long to reconsider their staunch resistance to such ventures. They have already submitted a list of camel breeders willing to break with tradition and have requested support in making the economic transition. Two nongovernmental organizations with which I am involved have taken up their proposal and have launched the Camel Husbandry Improvement Project, or CHIP, to investigate how camel breeding can once again become economically rewarding.

Whether camel milk can now do for the Raikas what the camel cart did earlier remains to be seen. A prerequisite for milk production is a better fodder supply. The options that need to be explored are purchasing supplementary feed, rehabilitating communal grazing grounds, and reopening some of the forest areas in the Aravalli Hills to grazing. For the sake of the economic health of the Raikas, the survival of their camels, and the perpetuation of their traditional knowledge, I hope solutions can be found. □



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Humankind So Far

by Keith Branigan

We can follow them for only a short distance, the footprints of two remote ancestors who walked side by side 3.5 million years ago. A photograph of these footprints, which were preserved by falling volcanic ash at Laetoli, in what is now Tanzania, introduces the reader to *The First Humans: Human Origins and History to 10,000 B.C.*, the first volume in *The Illustrated History of Humankind.* The five-volume series traces the path of the human race, from four million years ago to the present day. More than 150 specialists in the myriad sciences that contribute to modern archeology have collaborated in the production of this landmark project, and they tell the tale with enthusiasm and conviction. A fine array of maps and time-charts accompany the text and clarify the often complex but always intriguing story. Inevitably, though, the illustrations and photographs are what capture both our eyes and imaginations.

In a traditional initiation rite, a Tierra del Fuegan wears body paint and a bark mask to impersonate a spirit.
AMNH

The richness and variety of human experience and expression seem almost limitless. Diets and lifestyles are as different from one another as those of arctic hunters and fishers are from those of New Guinean fruit and root-crop growers. The same may be said of domestic architecture, from Omaha Indian earth lodges to Anglo-Saxon high-roofed timber halls to the severe brick houses of the Indus Valley people. This diversity reflects the adaptability, ingenuity, and creativity that seem to be constant, common elements of human history.

Humans have not only adapted to local ecological niches but they have also fine-tuned their lifestyles over time as environments have changed. Few challenges were more far-reaching than those presented at the end of the last great ice age, and no response could have been more successful than that of the hunters and gatherers of twelve thousand years ago, who made the first bows and arrows and contrived a variety of fish traps to exploit the changing fauna that appeared as the ice retreated.

The ingenuity of humankind from earliest times is evident in how hunters in Siberia, Australasia, and the Americas independently developed carefully controlled ways of heating raw flint and shaping it into stone tools. Ancient Britons erected Stonehenge, the Greeks invented the water clock, and the seagoing people of Micronesia created navigational charts of bamboo. Creative humans discovered how to make practical containers of pottery and forge metal from lumps of clay or rock.

Societies in different times and places devised writing systems to make and preserve a concise record of thoughts, words, transactions, and deeds. Among them were the Egyptians, who emphasized lifelike hieroglyphs, and the Mesopotamians, who rapidly developed their first, pictographic script into a complex writing system involving combinations of wedge-shaped strokes. In both societies, people learned to use visual images to convey not only material and abstract ideas but also

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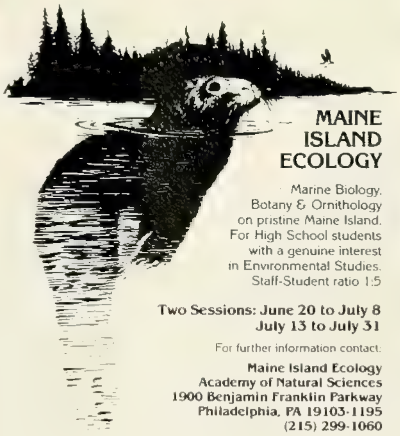
THE ILLUSTRATED HISTORY OF HUMANKIND, edited by Göran Burenhult. VOL. 1, THE FIRST HUMANS: HUMAN ORIGINS AND HISTORY TO 10,000 B.C. VOL. 2, PEOPLE OF THE STONE AGE: HUNTER-GATHERERS AND EARLY FARMERS. VOL. 3, OLD WORLD CIVILIZATIONS: THE RISE OF CITIES AND STATES. VOL. 4, NEW WORLD AND PACIFIC CIVILIZATIONS: CULTURES OF AMERICA, ASIA, AND THE PACIFIC. VOL. 5, TRADITIONAL PEOPLES TODAY: CONTINUITY AND CHANGE IN THE MODERN WORLD. *HarperSan Francisco; each volume is $40 and 239 pp., illus.*



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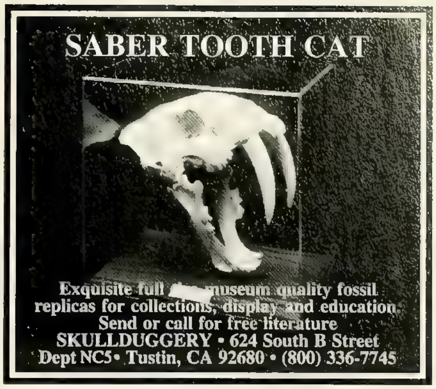

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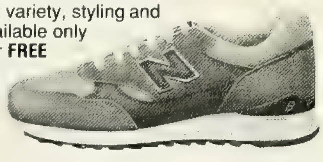

the sounds of a spoken language. The Mesopotamians were content to keep their documents on cumbersome clay tablets, while Egyptians and Chinese developed papyrus and paper, respectively.

The power of human imagination is graphically illustrated on page after page of these volumes, not least in the depictions of mythical creatures and supernatural deities. Whether supernatural images were painted in caves in southern Europe, etched on the rocks of Scandinavia, sculpted from stone in ancient Egypt, or carved from wood in North America, they represented a common human response to the contemplation of the unknown. And the monumental temples and tombs of the Aztecs and Maya, the Egyptians and Mesopotamians, and the ancient Khmer of Cambodia all testify to a peculiarly common response to a human dilemma: how to reach out to the gods.

When we look at some of the great structures of the past and contemplate the immense labor that went into building them, we are reminded of the roles of both individual leaders and the masses that followed them. In the case of the first Egyptian pyramid, history preserves the name of its designer—Imhotep—whose genius is still recognized and venerated millennia after his death. But many of the key steps forward in human progress were made by men and women who will forever remain unknown and unsung. That these steps were taken not once but many times in different eras and different places is an important message in *The Illustrated History of Humankind.*

But this observation raises in my mind the question of the darker side of humanity. A general tendency of the series as a whole is to present humankind as essentially decent folk, a view that I'm inclined to share myself. But as a prehistorian, I'm aware of the evidence from Knossos for possible ritualistic cannibalism about 1300 B.C. and of human sacrifice at Arkhanes about 400 years earlier. I'm also aware of the savagery with which the Assyrian army treated conquered peoples, and I know about Roman slavery and gladiatorial "games." In volume 3, *Old World Civilizations: The Rise of Cities and States,* which covers these societies, such practices are not discussed. According to the authors contributing to volume 4, *New World and Pacific Civilizations: Cultures of America, Asia, and the Pacific,* cannibalism, slavery, and human sacrifice appear as relatively new traits in the character of humankind, beginning in the second millennium A.D. Perhaps the authors and editors are assuming that before that time, such readings and interpretations of the clues to human behavior are difficult to document.

"The past is a foreign country; they do things differently there," wrote L. P. Hartley in *The Go-Between.* But is it? And do they? Throughout the pages of *The Illustrated History of Humankind,* many images will appear strange, unfamiliar, and foreign—the lifestyles of the Incas of Peru, the Minoans of Crete, and the Mauryas of northern India are different from twentieth-century Western society. So too are the more exotic present-day societies described in the fifth and final volume of the series, *Traditional Peoples Today: Continuity and Change in the Modern World.* The Nagai of Assam, the Lapps of the European arctic fringe, the Malagasy of Madagascar, and the Badui of Java reveal just as much diversity as the hunting and farming peoples of the past (depicted in volume 2, *People of the Stone Age: Hunter-Gatherers and Early Farmers*). Yet their very survival in a world dominated by industrial states is testimony to a common ingenuity, imagination, and creativity that has enabled them to adapt to a changing world and still maintain their traditions.

As David Hurst Thomas writes in the preface to the final volume, these people survive "not as living fossils but as living links to our long-term human past." They make the past that much more comprehensible. And if the past still remains "a foreign country," then it would be hard to find a better or more authoritative guidebook by which to explore its many fascinating pathways than *The Illustrated History of Humankind.*

Keith Branigan is the head of the Department of Archaeology and Prehistory at the University of Sheffield. The author of twenty books, mostly on Aegean prehistory and Roman archeology, Branigan currently runs field projects in eastern Crete and the Outer Hebrides.

Used for offerings, an Inca stone container was carved in the form of an alpaca.

John Bigelow Taylor; AMNH

EXOTIC DESTINATIONS

By Andrew Bill

EXOTIC DESTINATIONS

The world's great sites bring history to life

Cover Photo: Red-eyed tree frog by Tim Davis/Tony Stone

History, as it is written, has its fair share of detractors. Voltaire called it "the lie that historians agree upon." Henry Ford, as loquacious as ever, called it "bunk."

But history as it is seen, touched, and felt is an altogether different story. Historic sites present the past not as a grand political arena but as the small truths of daily life. Walking the overgrown roads of ancient abandoned cities, the visitors can weigh for themselves the hardships of daily life, the engineering feats, and the power of invention. In restored towns and mansions, they can follow myths back to their historic source, imagining the rattle of cups and the swish of ladies' silks as rich colonists sat down to tea. And in the great museums, they can see history, not through the distorting lens of someone else's analysis, but in a gold earring, a drinking vessel, or a child's battered doll.

Since many of the world's greatest historic sites are already well known, *Natural History* has collected some of the less familiar, yet no less worthy, examples that echo one significant period in their country's past.

Skagway

The Inside Passage, Alaska

In 1896 the *Seattle Post-Intelligencia* carried a front-page article about a ton of gold arriving by ship from Alaska, thereby launching the last of the great North American gold rushes. Thousands of fortune seekers headed north, turning the small town of Skagway, eighty miles northeast of Juneau, into "a nest of ants taken into a strange country and stirred up by a stick," as pioneer John Muir put it. More than eighty saloons slaked prospectors' thirsts, "painted ladies" assuaged other appetites, and gambling rings—like "Soapy" Smith's—took whatever gold was left over.

Today Skagway may be sleepier, better painted, and more sanitized, but it remains the most perfectly preserved of all the gold rush towns in southeastern Alaska. Modern visitors can walk down the shaded boardwalks, past the old storefronts, catching the occasional glimpse of a parasol twirled by a lady (no longer painted) in period dress. In the Klondike Gold Rush National Historic Park, they can experience re-creations of wild-west dramas, ride the narrow-gauge WP&YR railroad, pan for gold, or stroll through the Trail of '98 Museum housed in Alaska's first granite building. At night they might retire to their room in the Skagway Inn, a former brothel in the heart of the historic district.

Port Arthur

Tasmania, Australia

An early chapter in Australia's raw and colorful story tells of ship-loads of British convicts deported to the east coast to serve out their sentences in grueling conditions. Those interested in reading between the lines should travel south to Port Arthur just southeast of Hobart on the Tasman Peninsula.

Between 1830 and 1877, some 12,500 "multiple offenders" were sent to Port Arthur as cheap and dispensable labor essential to the thriving of Britain's colonial machine. The penal system of that time

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EXOTIC Thailand

"Royal Grand Palace and The Emerald Buddha Temple", *Bangkok*

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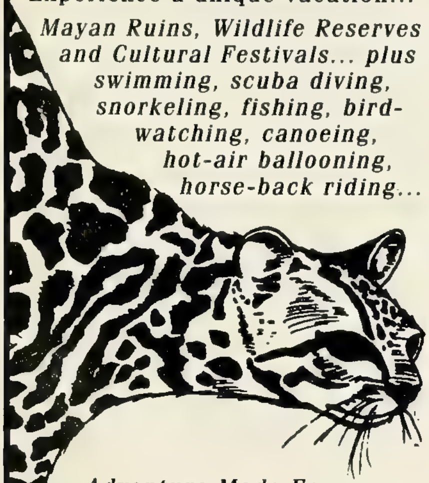

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Australia's notorious Port Arthur Prison

was not noted for its soft hand, a fact that shouts out grimly from stories of man-hunting hounds—and from and surviving structures like the penitentiary (the model prison) and the third link in the chain for the unfortunates: the asylum. Many didn't even make it that far and, after briefly requiring the services of the church (still standing), were buried in mass graves on the nearby Island of the Dead.

Even now the past is still palpable, calling out from the empty buildings, the vacant barred windows. You can aid the imagination by walking through the museum, seeing the well-worn tools, the items used for discipline, and those small comforts of the prison officials. And if that is not enough, you can sign up for the after-dark "ghost tour" that trails through the buildings with their dark stories, silhouettes, and shadows.

Yellowknife

Northwest Territories, Canada

As the world is miniaturized by jet travel, even far-flung destinations are being tamed by tourism. One notable exception is the "Great White North" of Canada, where visitors are invariably caught by the magic of the land and by the history that runs through it like the rich veins of gold that once made this area famous.

Ever since the early 1700s white traders from the Hudson Bay Company have shared the land with the Inuit and Dene hunters. To those who visit Yellowknife today, those three hundred years seem like yesterday. Old-time miners and optimistic prospectors still walk the city's streets; a Bristol bomber sits on a rocky outcrop as a tribute to the first wheeled aircraft to land on the North Pole in 1967; and the Old Town retains its nostalgic mood. Its Native Arts and Cultural Center, gold mines, and fatigued clapboard houses add the atmosphere. The Prince of Wales Northern Heritage Center provides the details: within its many galleries you can see a boat made out of moose hides, the tools that originally built the town, and everyday relics from its earliest days. Those who want to climb into the shoes of the first gold miners can sign up for an underground tour of one of the nearby mines. The best time to visit (from a climatic, ease-of-traveling standpoint) is between mid-March and late August.

Guayabo National Monument

The Meseta Central, Costa Rica

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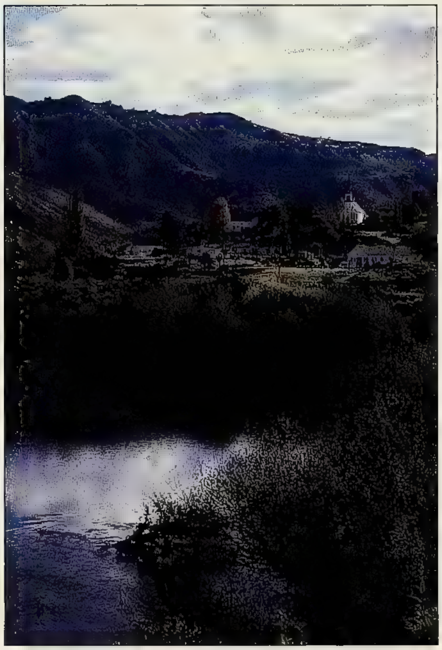
terrains, preserved in fifteen national parks like Guanacaste in the north and Corcovado in the south. Yet those who seek to mix their nature with history would do well to include Costa Rica's most important archaeological site, Guayabo, in their next itinerary.

Start in the capital, laying the groundwork with a tour of the worthy museums. The Jade Museum, the largest collection of American jade in the world, displays ancient idols and objects of personal adornment. The Gold Museum follows a similar but even richer theme, and the National Museum contains everything from archaeological treasures to flora and fauna. Now you are prepared for the field trip, first to Turrialba (40 miles east of San José) by rental car, then on to Monumento Nacional Guayabo. Hugging the side of a volcano and carpeted with misty rain forest, the park presents history in the raw—fifty excavated sites, including plazas cut out of the forest, a collection of ancient bridges, aqueducts, roads, monoliths, and petroglyphs—hinting at the city's glory days prior to the fifteenth century and waiting to be discovered by keen-eyed visitors hiking the paths that lace through the vegetation. The best time to visit is in the dry season, January through May.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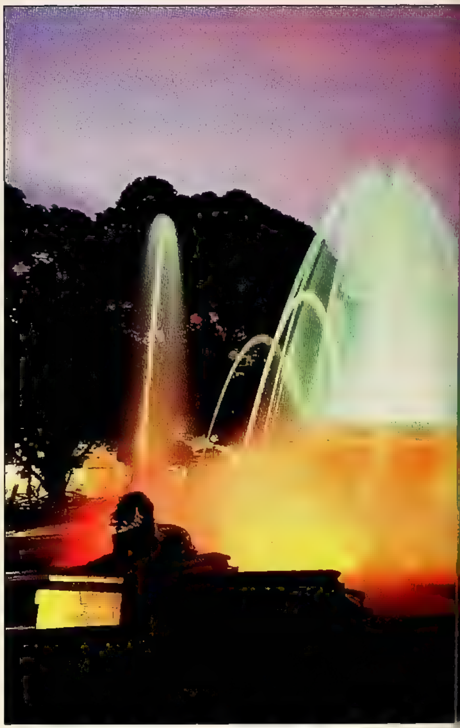
The Maori village of Jerusalem along the Wananui River

Wanganui River

North Island, New Zealand

Best known for its pristine nature, New Zealand also has a colorful past often overlooked by visitors. Cutting sideways through the strata of this history is a drive up the left bank of the River Wanganui that flows into the South Taranaki Bight north of Wellington.

The story of the islands' colonization starts to unfold just eight miles out of the town of Wanganui as the visitor enters Upokongaro. Here stands Saint Mary's Anglican Church, built in 1877, with its curious steeple overlooking the river. Upstream from this religious monument lies a secular site, illustrative of the colonists' more temporal concern, Buckthorpe's Redoubt—a lookout post to watch for hostile Maori approaching from the north. Driving a few miles along the route, which is as scenic as any in the North Island, you arrive at Atene (Athens), where an old meeting house hints at a former settlement. This is a good spot to park the car and set off along the Atene Skyline Walk, which takes between six to eight hours round-trip.



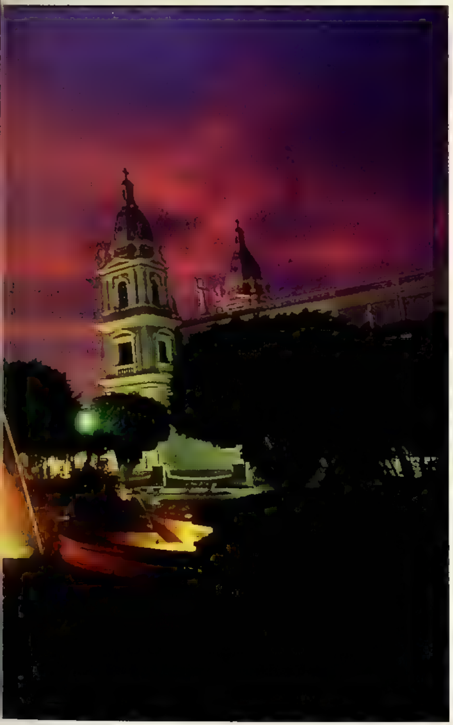
Plaza las Delicias, Ponce, Puerto Rico

As the road cuts further inland, its sites turn from the colonists to the world of the native inhabitants, the Maori. Korinti (Corinth) used to be one of the largest Maori settlements on the river, a legacy marked by two splendid carved houses. And in Operiki pa, huge earthworks recall stories of the hostility between neighboring Maori tribes, of primitive siege machines, and of a variation on the Trojan Horse bait-and-switch technique. But the high point of the journey is surely reaching the tiny village of Jerusalem, the center for Maori in the Wanganui hinterland made famous by the philanthropy of Mother Mary Joseph Aubert (1835 to 1926).

Ponce
Puerto Rico

San Juan seems ever in the spotlight. It's the capital city where the modern nudges up against the old—a living museum of old streets, colonial facades and historic sites like the imposing fort of El Morro and the charming house and gardens of Ponce de Leon. But across the island stands Ponce, the "pearl of the south," a city different and perhaps even more deserving of a visit than its higher profile sister.

Originally a sleepy southern town, Ponce sprung up in the early 1800s as a prosperous port and cultural center made rich by coffee and sugar. But in the 1930s, when the bottom fell out of both crops, Ponce was frozen in time. Today more than half of the city's 1,000 historic sites have been restored to their former grandeur. The main streets are lit by replica gas-lamps and trimmed with locally-quarried pink marble. The tree-lined Plaza las Delicias (Plaza of Delights) is a charming neoclassic square dominated by the blazing-white facade of the seventeenth-century cathedral and the glaring black and red of its firehouse. Only a few minutes walk away, the modern Ponce Museum of Art houses an extensive collection of big-name art from both Europe (mostly Italian baroque and pre-Raphaelite) and the Caribbean. The Museum of Music (once a private home of one of Puerto Rico's most regarded architect, Bertoli Calderoni) now charts the evolution of the island's music a heartbeat from the African-inspired bomba to today's salsa. And there's the Greek-revival Teatro la Perla, a theater for evening concerts and plays that allows visitors to tap into the island's cultural pulse.



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The former Siamese capital of Ayutthaya

Ayutthaya

Thailand

The traveler who goes to Thailand in search of history never has far to look. The modern capital Bangkok alone presents a world of options, from tiny back-street temples ablaze with candles and fragrant with incense to the Grand Palace, an explosion of gold and opulence. But nearby is Ayutthaya, a capital of Siam for four centuries (until 1767) and now a UNESCO World Heritage Site.

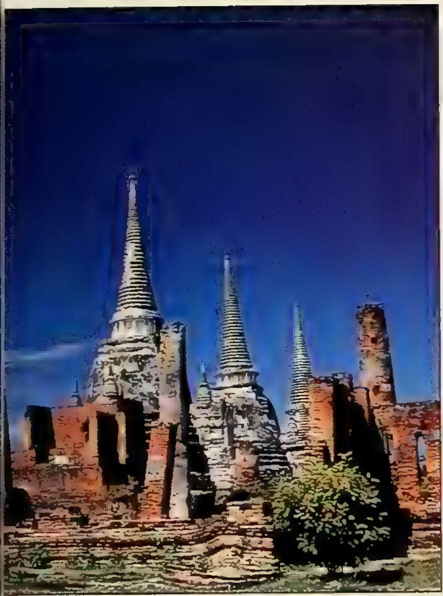
Ayutthaya represents Siam's glory years when the East was opening up to international trade. Today you can see the results in the Historic Park, the core of the old state that once spread out as far as the Malay Peninsula to the south and to Myanmar (formerly Burma) in the north. Here brick pathways lead past sculpted walls, with faces and limbs of the gods staring out of the moss. Huge wats, solid pyramidlike structures, force their way up into the sky like eccentric wedding cakes. One of them, Vihara Phra Mongkol Bopitr, contains one of the largest coated-bronze Buddha images in the country. At another, Wat Ratburana, dozens of gold artifacts were discovered in 1958 and put on display in the Ayutthaya National Museum.

Charlotte Amalie

Saint Thomas, United States Virgin Islands

Many Americans, longing for the cocktails-by-the-pool, tend to overlook the Caribbean's historical dimension. But for those who look behind the curtain, the backstage is filled with blood-thirsty pirates, gracious living on sugar plantations, and dueling European nations with insatiable colonial appetites—a history illustrated by Charlotte Amalie.

Charlotte Amalie is the capital of Saint Thomas, the most active and developed of the three U.S. Virgin Islands. Yet even here in this bustling port, the island's past is poised to snare the imagination. On Synagogue Hill stands the oldest synagogue in continuous use under the American flag, dating back to 1833. It houses Torah scrolls over two centuries old and a menorah made in the eleventh century. The Jewish congregation on Saint Thomas celebrates its bicentennial next year. Even earlier is Fort Christian (1680), the Danish fortress with heavy brick and rubble walls and a dungeon that now serves a more salubrious purpose—as a museum. The five-



Tourism Authority of Thailand

story Skytsborg Tower on Government Hill (1678), is rumored to have served as a hideout for the scourge of the shipping lanes, Edward Teach (a.k.a. Blackbeard), the original walk-the-plank pirate. And a reminder of a more civilized period can be found in Government House, the elegant home of the island's governors since 1876.

Andrew Bill is a free-lance journalist based in New York and specializing in travel and design.

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Seventeenth-century Fort Christian in Saint Thomas

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The Coriolis Force

by Neil de Grasse Tyson

I am often asked by students whether their toilet bowls will flush clockwise or counterclockwise in the Southern Hemisphere. This would, of course, be important information if you were ever kidnapped and blindfolded and dropped off in a strange land. If we assume a commode of conventional size, then this "toilet bowl test" will fail because the answer lies in the manufacturer's design. But if your toilet bowl were a few hundred miles in diameter, then the Coriolis force of the rotating Earth would easily overcome the random water currents and force the bowl to empty its contents in a counterclockwise swirl. If you had Southern Hemisphere friends with an equally large toilet, then theirs would indeed empty in the opposite (clockwise) direction.

The circulation within oversized flush toilets is a natural consequence of motion on the surface of an object that rotates. We owe our detailed understanding of the effect to the French engineer and mathematician Gaspard Gustave de Coriolis, who, in 1835, described the laws of mechanics in a rotating reference frame.

Earth's surface is an excellent place to demonstrate why the origin of the Coriolis force is relatively simple. Our planet rotates on its axis approximately once every twenty-four hours. Over that period, objects on the equator travel a circle with a circumference of nearly 25,000 miles, which corresponds to a speed of more than 1,000 miles per hour. By forty-one degrees north, the latitude of New York City and the American Museum of Natural History, the circumference traveled is only about 19,000 miles, and the west-to-east speed is approximately 800 miles per hour. As you continue to increase in Earth latitude (north or south of the equator), your west-to-east speed decreases until it hits exactly zero miles per hour at the poles. (For this reason, most satellites are launched as close to the equator as possible, enabling them to get a good "running start" in their eastward orbits.)

Imagine a puffy cloud in the Northern Hemisphere and a meteorological low-pressure system directly to its north. The cloud will tend to move toward the low. But during the journey, its greater eastward speed will enable the cloud to overtake the low, which is itself in motion, and end up east of its destination. Another puffy cloud that is north of the low will also tend to move toward the low, but will naturally lag behind and end up west of the system. To an unsuspecting person on Earth's surface, these curved north–south paths would appear to be the effects of a mysterious force (the Coriolis force), yet no true force was ever at work.

When puffy clouds approach a low-pressure system from all directions, you get a merry-go-round of counterclockwise motion, better known as a cyclone. In extreme cases, you get a monstrous hurricane with wind speeds upward of a hundred miles per hour. In the Southern Hemisphere, the same conditions will create a cyclone that spirals clockwise. Those in the military who target missiles and artillery shells know all about the Coriolis force and normally calculate the appropriate corrections needed for accuracy. In an embarrassing military moment of World War I, English battle cruisers engaged two German warships at a range of nearly ten miles near the Falkland Islands in the Southern Hemisphere—but they forgot to reverse their Coriolis correction. Despite this and other gunnery problems, the English eventually won the battle with about sixty direct hits but not

The Great Red Spot is a high-pressure anticyclone that has been raging on Jupiter for more than 300 years. It is the solar system's most dramatic display of the Coriolis force. Three of Jupiter's moons are visible in this image taken by Voyager 1.

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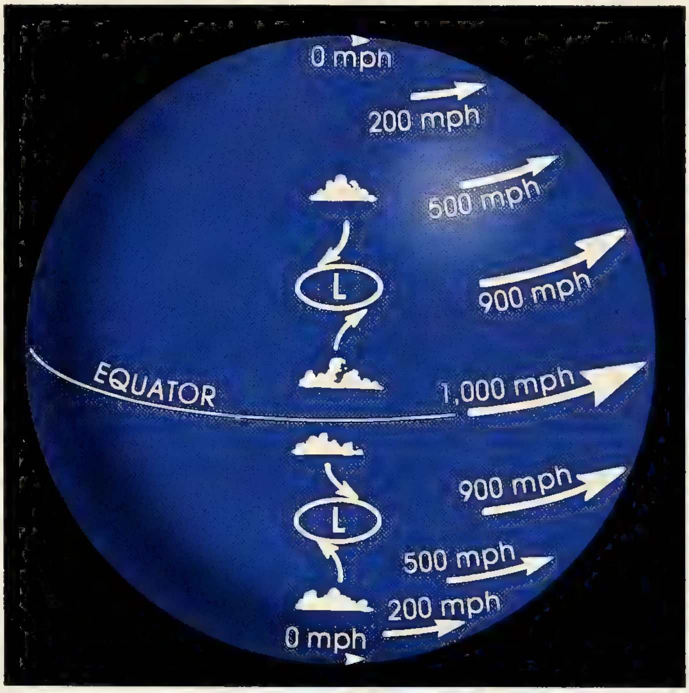
before more than a thousand missile shells had fallen in the ocean.

In high school I knew all about the Coriolis force, but I never had the opportunity to test it on something as large as a swimming pool until the summer after my junior year when I worked as a lifeguard. At the midsummer cleaning, I carefully opened the drain valve to the pool and observed the circulation. The water funneled in the "wrong" direction—clockwise. The last time I checked, I was life-guarding in Earth's Northern Hemisphere, so I was tempted to declare the Coriolis force a hoax. But a fast back-of-the-envelope calculation verified that the difference in Coriolis velocity across the pool was a mere half inch per minute. This is slow. The water currents from somebody just climbing out of the pool or even a gentle breeze across the water's surface would easily swamp the effect, and I would end up clockwise half the time and counterclockwise the other half. To demonstrate the insignificance of the Coriolis force on this scale would have required emptying and refilling the pool dozens of times. But each try would dump 15,000 cubic feet of water and diminish my job security. So I didn't.



Because they must travel farther around Earth's axis every twenty-four hours, regions near the equator move west-to-east faster than regions near the poles. Consequently, Northern Hemisphere clouds drawn toward a low-pressure system will overtake it if they are to its south and lag behind it if they are to its north, resulting in the familiar counterclockwise circulation of a cyclone. The deflection from a straight path is explained by the Coriolis force. Low-pressure cyclones in the Southern Hemisphere, for analogous reasons, rotate clockwise.

Dennis Davidson; Hayden Planetarium

The air circulation near high-pressure systems, which are inelegantly known as anticyclones, is a reverse picture of our cyclone. On Earth, these high-pressure systems are the astronomer's best friend because they typically repel clouds. The surrounding air still circulates, but it does so without the benefit of clouds as tracers. The circulation around low- and high-pressure systems, known as geostrophic winds, presents us with the paradox that the Coriolis force tends to move air along lines of constant pressure (isobars), rather than across them.

Now imagine, if you will, a place that is 1,400 times larger than Earth, has an equatorial speed that is about twenty-five times as fast, and has a deep, thick, colorful atmosphere. That place is the planet Jupiter, where a day lasts just nine hours and fifty-six minutes. Jupiter is a cosmic garden of atmospheric dynamics where all rotationally induced cloud and weather patterns are correspondingly enhanced. In the most striking display of the Coriolis force in the entire solar system, Jupiter lays claim to the largest, most energetic, and longest-lived storm ever observed. It is an anticyclone that looks like a great red spot in Jupiter's upper atmosphere; we call it Jupiter's Great Red Spot. Discovered in the mid-1660s by the English physicist Robert Hooke and, separately, by the Italian astronomer Giovanni Cassini, the feature has persisted for more than 300 years. But it was not until the twentieth century that the modern interpretation of the Spot as a raging storm was supplied by the Dutch-born American astronomer Gerard Kuiper.

The Great Red Spot is bigger than Earth, but its size and shape have varied over the years. It lives in Jupiter's southern hemisphere and rotates counterclockwise, which immediately tells us we have a high-pressure system. The coloration, from orange red to a barely visible pale cream, is generally attributed to various concentrations of phosphorus and sulfur compounds. Close-up images from the *Voyager* flyby missions of the late 1970s revealed a maelstrom of colorful curlicues at the interface of the Great Red Spot and the surrounding atmosphere. There were also strikingly resolved horizontal "belts" and "zones," interlaced with countless smaller cyclones and anticyclones, which give Jupiter the appearance of an archeological cross section of a Big Mac hamburger, bun included. Above all else, however, the *Voyager* data posed renewed theoretical challenges. They resolved Jovian features down to twenty miles in diameter—astonishingly small when one remembers Jupiter's size relative to Earth's. Models of cosmic phenomena are often clean and tidy until they are tested outside of the limits in which they were formulated. When higher image resolution comes along, for example, many models are discarded, others are modified, and some are freshly invented. But jumps in resolution have always been followed by a deeper understanding of the universe.

Whatever else a model of Jupiter's atmosphere is designed to explain, it should as a minimum account for basic properties of the Great Red Spot, such as its longevity, its distinguished size, and that it is an anticyclone. An ideal model would be able to account for all atmospheric motion on Jupiter. The tools available to the theorist are Newton's laws of motion as adapted to the properties of gases and liquids—otherwise known as fluid mechanics.

Although little is known about the structure of Jupiter's underlayers, contemporary models do capture the basic feature of the Great Red Spot. Jupiter radiates more heat than it receives from the sun and has enormous interior thermal reservoirs that can drive its atmospheric flow patterns. One source is the radioactive decay of trace elements, while another is the leftover heat from Jupiter's initial contraction from a protoplanetary cloud to a planet in the early solar system. The sustained source of en rgy for the Spot could also (or instead) be apped from other sources. On Earth, hur-icanes are partly driven by the latent heat eleased to the atmosphere when raindrops ondense out of the air. A similar mechanism may dominate in Jupiter's atmosphere as its gases condense toward its liquid interior. The Spot has also been observed (and successfully modeled) to line upon smaller, turbulent eddies in its vicinity. This cannibalistic behavior is yet another source of energy. Clues to the leeper cloud layers will be gained when he spacecraft *Galileo* passes Jupiter (in December 1995) and parachutes a niniprobe that will measure temperature, lensity, composition, wind speeds, and electrical storms as it descends through the outer atmosphere.

For now, there is no reasonable hope of lescribing every one of Jupiter's surface eatures in detail. A more realistic approach is to construct an atmospheric nodel that provides a statistically equivalent picture of Jupiter's surface features. In other words, a model of a Big Mac can approximate all Big Macs even though it may not look like any one in particular.

One nagging problem with models that always produce a single, sustained anticyclone is the blunt reality that Jupiter's northern hemisphere is devoid of a twin Great Red Spot. Clearly, if models show that big spots are inevitable, then the north ought to have one, too. Elsewhere in the solar system, the Coriolis force has given rise to what is called Neptune's Great Dark Spot. Like Jupiter's Great Red Spot, it is a southern hemisphere anticyclone of epic proportions without a twin in the north. This is a problem that may require an as-yet-unexplored north–south asymmetry in both Jupiter's and Neptune's internal structure. One way to create such an asymmetry would be a cosmic collision. The July 1994 encounter between Jupiter and the dozens of crumbled comet parts from Shoemaker-Levy 9 left visible and sustained scars on Jupiter's outer gaseous surface. The long-term effects of this impulse of deposited energy remains to be seen. Will the scars form stable new structures among the cloud tops? Or will the scars dissipate completely into the atmosphere? For the moment, feel free to consider the new blemishes to be extra ingredients in your hamburger.

Neil de Grasse Tyson is an astrophysicist with a joint appointment at the American Museum–Hayden Planetarium and Princeton University.

CELESTIAL EVENTS

by Joe Rao

For the second time this year, we have two new moons in a month, a byproduct of our calendar's being out of sync with the lunar phases. (About twenty-nine and a half days elapse from one new moon to the next.) With the first new moon occurring on the 1st at 6:49 A.M., EST, this month is as good a time as any to follow the regular progression of the moon's phases. A few rules will help. When new, the moon is passing close to the sun, so we can't see it (except on those rare occasions when it eclipses the sun). Within a day or two, however, the moon makes its first appearance as a delicate, thin arc adding beauty to the western twilight. With each passing night, it moves away from the sun, setting and rising about fifty minutes later.

For nearly a week after the new moon, the crescent appears to enclose a ghostly ball, as the night side of the moon is dimly illuminated by light reflected from the earth. The tilt of the crescent depends upon the season and latitude of the observer. In late winter and early spring, for example, a line drawn between the cusps of the crescent is nearly horizontal. Because the moon resembles a cup that might hold water, it is often called a "wet" moon.

Each night, the illuminated portion of the lunar surface brightens and spreads from right to left until the moon forms a neat half disk—first-quarter phase, which occurs on the 9th this month at 5:15 A.M., EST. At this moment, the lunar terminator (the edge between day and night on the moon) appears more or less straight. If you have a small telescope, this is the best time to watch the effects of the sunrise on the moon. As the illumination of craters and mountains changes, the shadows they cast move across the lunar surface, changing its appearance.

Because the moon may be below the horizon, you can't always see a straight terminator on the moon when the almanac predicts first quarter. This month the first-quarter moon is below the horizon for observers in New York, so on the evening of the 8th, the moon will still be a crescent with a concave terminator; on the 9th, it will already be gibbous with a convex terminator.

Similarly, on the calendar date of a full moon, the left or right edge may appear slightly shaved off. This month's full moon is above the horizon for observers in the eastern and central United States (8:26 P.M., EST, on the 16th), but next month it will be below the horizon for most observers. (Full moons rise in the east as the sun sets in the west.) When full, the moon is considerably brighter than it is at any other phase. At first quarter, the moon is only one-eleventh as bright as when it is full.

THE PLANETS IN MARCH

Mercury is very close to the east–southeast horizon on the 1st at about forty-five minutes before sunrise. Look for it 15 degrees to the lower left of Venus. Binoculars may be necessary, especially for viewers in the northern United States, where the bright morning twilight will interfere with viewing after the first week of March. Observers in the South should watch for the close approach of Mercury and Saturn on the 26th; the smaller planet shines four times as brightly as Saturn and passes just below and to the right of it.

Venus is unmistakable at magnitude –4, but is rather low in the predawn sky. The planet is now ahead of Earth in its orbit around the sun, but its twenty-two-mile-per-second motion is only slightly faster than Earth's eighteen miles per second. As seen from Earth, Venus will take about seven months to pass behind the sun. A waning crescent moon will pass high above Venus on the mornings of the 27th and 28th.

Mars is above the northeastern horizon at dusk and is visible for most of the night. Just past opposition, Mars begins to fade. Starting the month at a distance of 65.9 million miles and magnitude –0.9, the planet will have dropped to magnitude –0.2 by month's end, as the separation between Earth and Mars widens to 82.8 million miles.

Jupiter shines prominently in the southern sky at dawn. On the morning of the 22d, look for Jupiter below and to the left of the waning gibbous moon.

Saturn is in conjunction with the sun on the 6th, when it enters the morning sky. Observers in the southern United States may catch a brief glimpse of the planet as early as March 26, when it appears as a yellowish white "star" of first magnitude, rising above the east–southeast horizon about forty-five minutes before sunrise.

The **Moon** is new on the 1st at 6:49 A.M., EST; first quarter is on the 9th at 5:15 A.M., EST; full moon is on the 16th at 8:26 P.M., EST; and last quarter is on the 23d at 3:11 P.M., EST. A second new moon in March occurs on the 30th at 9:09 P.M., EST.

The vernal equinox takes place at 9:14 P.M, EST, on March 20. Spring officially begins in the Northern Hemisphere and autumn starts in the Southern Hemisphere.

Joe Rao is a meteorologist and a guest lecturer at the American Museum–Hayden Planetarium.

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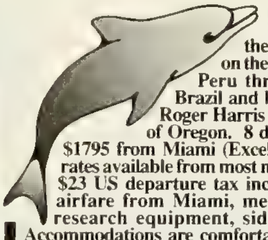

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SPIDERS!

An exhibition exploring the world of spiders will open Friday, March 17, in Gallery 3. Spiders evolved at least 380 million years ago, and to date an estimated 36,000 species have been identified. Among the topics of the exhibition will be spider diversity and range of habitats; the dangers and benefits of spiders to humans and a balanced ecosystem; spider behaviors, such as courtship, mating, and feeding habits; web architecture and spider defensive tactics; and the folklore, literature, and legends associated with spiders. The exhibition will run through Sunday, June 4. In conjunction with the exhibition, spider researcher and photographer Simon Pollard, a zoologist from the University of Canterbury, New Zealand, will give a slide-illustrated talk on Tuesday, March 21, at 7:00 P.M. Tickets are $12. For information, call (212) 769-5310.

TOWARD THE ARCTIC OCEAN AND THE NORTH POLE

Kenneth A. Chambers, author, lecturer in zoology, and scholar of polar history, will talk about arctic exploration on four consecutive Wednesday evenings at 7:00 P.M. in March. His lectures cover the following topics: "Northern Seas and Arctic Explorations" on March 1; "In Search of the Franklin Expedition" on March 8; "Amundsen and Ellsworth Conquer the Arctic" on March 15; and "Ringing the Pole—The Northern Sea Route's Northeast Passage" on March 22. Tickets for the series are $30. Call (212) 769-5310 for information.

SACRED DEEDS: NATIVE AMERICAN LAND CONSERVATION

Native American attitudes toward land and private ownership—their implications and associated issues—will be the subject of a talk by Ronald S. McNeil, a member of the Hunkpapa band of the Lakota Sioux Nation and president of the American Indian College Fund. The talk will be presented on Monday, March 20, at 7:00 P.M. in the Kaufmann Theater. Tickets are $12. For information, call (212) 769-5310.

CITY ANIMALS: FACT AND MYTH

On Saturday, March 11, naturalist Bill Robinson will introduce some of the wild animals that have at times made their home in New York City. Among the "residents" will be an opossum, an eight-foot-long alligator, a peregrine falcon, a red-tailed hawk, a cormorant, and a giant hissing cockroach. The presentation, for ages five and up, will take place at 11:30 A.M. and 1:30 P.M. in the Kaufmann Theater. Call (212) 769-5606 for information.

WOMEN'S HISTORY MONTH

In March, the Museum will celebrate Women's History Month. Demonstrations, lectures, and other programs will be presented as part of the Education Department's year-long series "Unity Through Diversity." For a brochure and further information, call (212) 769-5315.

CLASSICAL MUSIC AND DANCE OF KOREA

A ten-member ensemble of master musicians and dancers from the Korean Traditional Performing Arts Centre/Seoul will perform on Wednesday, March 29, in the Main Auditorium at 7:30 P.M. The program will include ancient Chinese court dances and ritual music, classic works from Korean Confucianism, and processional music rarely presented outside of Korea. Tickets are $8 ($6 for members). A demonstration of Korean musical instruments and dance will be given on Tuesday, March 28, at 7:00 P.M. Admission is free for the first 300 people holding a concert ticket. Call (212) 769-5315 for more information.

A robe of jingling snail shells worn by a Yoruba masquerader creates comic relief during serious ceremonies. The robe, on display in the Hall of African Peoples, is one of fifty treasures featured in the Museum's 125th-anniversary "Expedition" tours.

AMNH: Beckett/Chesek

CHILEAN FESTIVAL

In conjunction with the Mission of Chile to the United Nations, the Education Department will present a minifestival of films and performances that celebrate Chilean culture and reflect the country's social, political, and environmental conditions. Featured will be jazz and contemporary folklore music by Grupo Congreso on Wednesday, March 8; rock folklore music by Los Tres on Sunday, March 19; and a film festival from Friday, March 24, through Sunday, March 26. Tickets are $5 per program ($4 each for two or more programs). For a complete schedule, call (212) 769-5315.

VOIDS IN SPACE

Stephen Gregory, a professor of astronomy at the University of New Mexico, will give a slide-illustrated talk on Monday, March 13, on the subject of voids in space. This lecture is part of the "Frontiers in Astronomy and Astrophysics" series and begins at 7:30 P.M. Tickets are $8 ($6 for members). Call (212) 769-5900 for information about all Planetarium events, including the Sky Show "The 10 Most Asked Questions About the Universe," and the exhibition "The Universe Revealed: Recent Images from the Hubble Space Telescope."

CLARENCE S. BEMENT: THE CONSUMMATE COLLECTOR

In 1900, Museum trustee J. Pierpont Morgan, Sr., presented the Museum with Clarence S. Bement's mineral collection: 12,300 specimens, including 769 varieties of minerals and 500 meteorites that were collected in the years after the Civil War. On Wednesday, March 8, at 7:00 P.M. in the Kaufmann Theater, Joe Peters, senior scientific assistant in the Department of Mineral Sciences, will talk about Bement and show slides of the collection's highlights. Call (212) 769-5606 for information.

THE JEWISH COMMUNITY OF BOMBAY

The 1978 film *About the Jews of India: Shanwar Telis or Bene Israel* portrays a 6,000-member Indian Jewish community in Bombay that subsequently emigrated to Israel. Filmmaker Johanna Spector will introduce the forty-minute film on Wednesday, March 22, at 7:00 P.M. in the Main Auditorium and will answer questions after its screening. For ticket availability and other information, call (212) 769-5606.

GEOLOGY FOR TRAVELERS

In a three-part, Tuesday-evening lecture series, Sidney S. Horenstein, geologist and coordinator of environmental public programs at the Museum, will introduce some fundamental concepts in geology and suggest how to apply them when traveling. The subjects of his talks are "Basic Geological Principles" on March 21, "Landscape Classification" on March 28, and "Geological Structures" on April 4. Tickets for the series are $25. Call (212) 769-5310 for information.

MANKILLER: A CHIEF AND HER PEOPLE

In 1977, Wilma Mankiller became the first woman elected to preside over the Cherokee Nation. On Tuesday, March 28, at 7:00 P.M. in the Main Auditorium, she will talk about her people and her efforts to instill the spirit of community self-help in them. Call (212) 769-5606 for ticket availability and information.

MOUNTAIN WILDFLOWERS OF THE NORTH

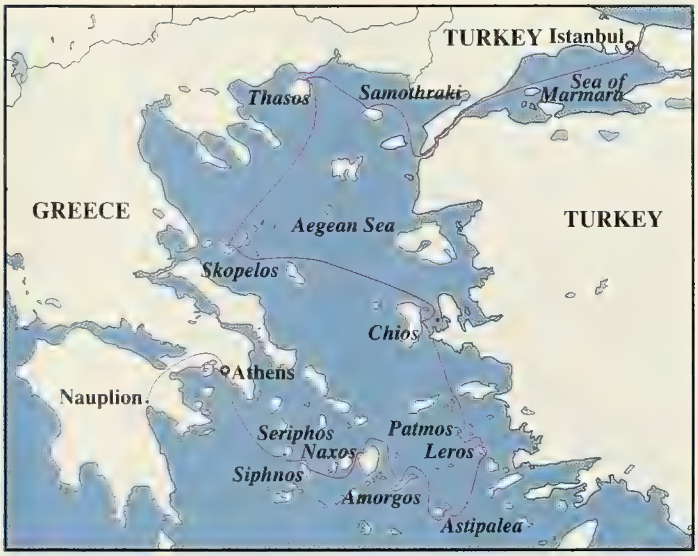
Complex orchids, colorful lilies, dwarf arctic creepers, ancient cushion plants, and other wildflowers of the North will be the subject of a lecture series given twice in March by William Schiller, lecturer in botany in the Education Department. The first program, four consecutive Thursday-evening talks, begins on March 2 at 7:00 P.M.; four consecutive Monday-afternoon talks begin on March 6 at 2:30 P.M. All lectures will be presented in the Blum Lecture Room. Tickets for the series are $30. For information, call (212) 769-5310.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater and the Blum Lecture Room are located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

American Museum of Natural History

THE UNDISCOVERED GREEK ISLES

September 23 - October 7, 1995



Scattered throughout the Aegean Sea are hundreds of islands, many of which are associated with Greek legend and history. Enchanting whitewashed towns, fruit groves, Greek and Roman ruins and Byzantine churches dot islands now rarely explored by travelers. This fall, the Dean of Science from the American Museum of Natural History will lead a cruise aboard the deluxe *Queen Odyssey* on a voyage of re-discovery—an opportunity to visit islands that were of great importance in antiquity and today retain a charm rarely found on well-known islands. Join us for an unusual voyage to some of Greece's "undiscovered" isles.

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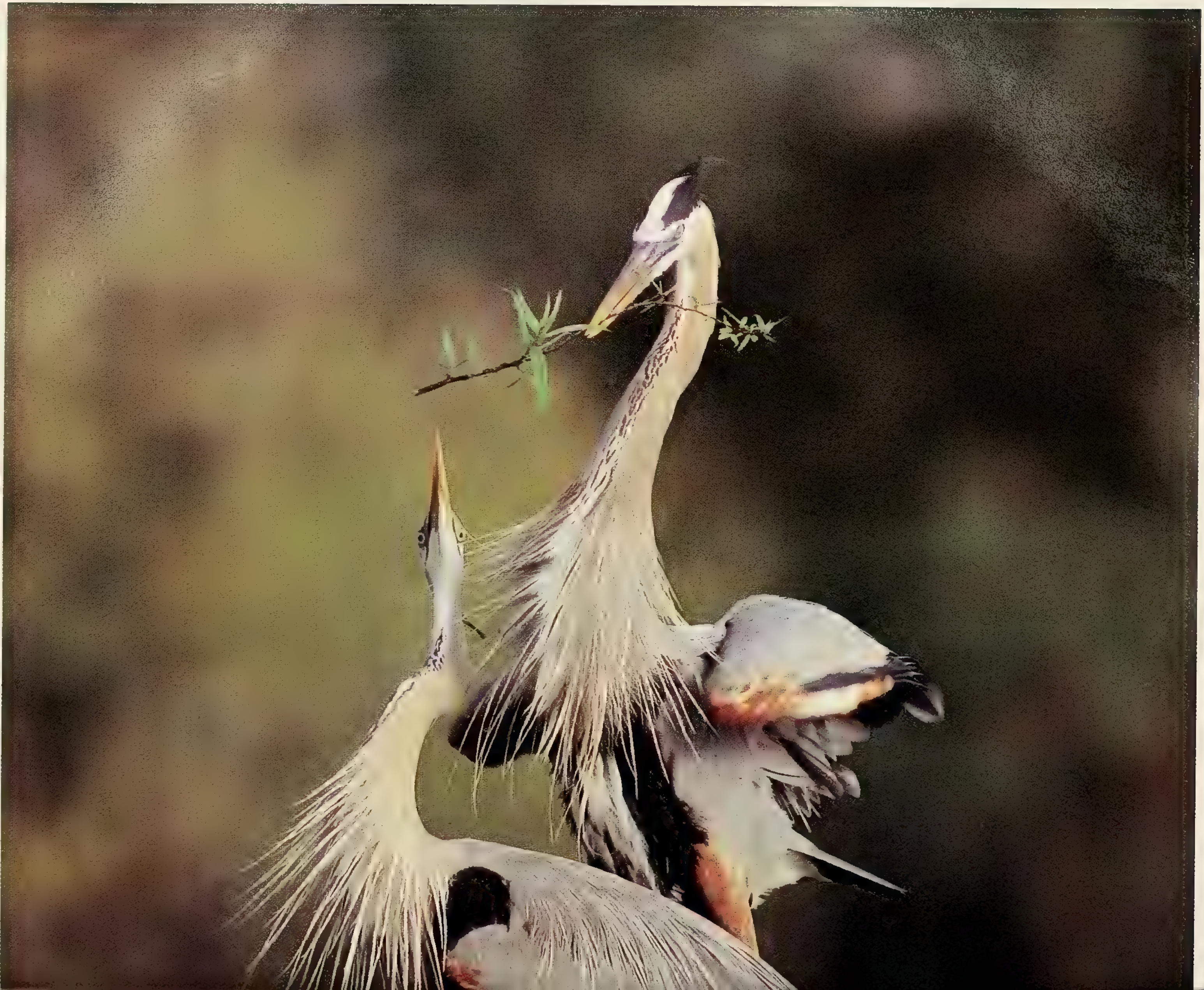


Standing on Ceremony

Photograph by Arthur Morris

Often solitary and always stately, great blue herons have an aloof air. A long-time student of great blues, ornithologist Douglas Mock finds these largest of North American herons downright standoffish, even during the breeding season. For this species, the vital but messy business of mating, nesting, and rearing young demands three months of shared effort by a monogamous pair. Such hormone-enforced intimacy is mediated by rituals—elaborate displays and posturing involving bills, necks, and nuptial plumage. To attract a female, a male usually stakes out an old nest—a sturdy platform of interwoven sticks—and displays from it. During courtship, the herons refurbish and add to the nest, and even after the eggs are laid, a female will accept her mate's gifts of sprigs and tuck them into the structure.

These great blues, their nest perhaps already holding eggs, are residents of an island rookery near central Florida's gulf coast. The imposing male shows himself to erect and full-feathered advantage and ritually presents a sprig. The female reciprocates with a stretch display and sky-points with her bill before accepting the offering. This twig-passing ceremony, undertaken many times a day, may mollify the otherwise aloof birds, whose pair bond Mock compares to a "grudging truce."—*J. R.*

AUTHORS

With New Zealand's Waimakariri River in the background, **Robert R. Jackson** (page 28) hunts for spiders in the brush. Jackson, who introduces the special section on spiders in this month's issue, was born in North Carolina but now calls New Zealand home. He completed his undergraduate degree at North Carolina State University in Raleigh in 1968, and eight years later finished his Ph.D. in zoology at the University of California at Berkeley. Jackson will travel just about anywhere to study a spider that interests him, and because he finds there is no such thing as a boring spider, his research has taken him to every continent except Antarctica. Currently, he is an associate professor of biology at the University of Canterbury, in Christchurch, New Zealand. He is now studying spiders that hunt other spiders, trying to figure out exactly how they use mimicry to lure their victims to within striking range. Next, he plans to travel to East Africa to study social jumping spiders. For a great introduction to spiders, Jackson recommends Rainer F. Foelix's *Biology of Spiders* (Cambridge: Harvard University Press, 1982).

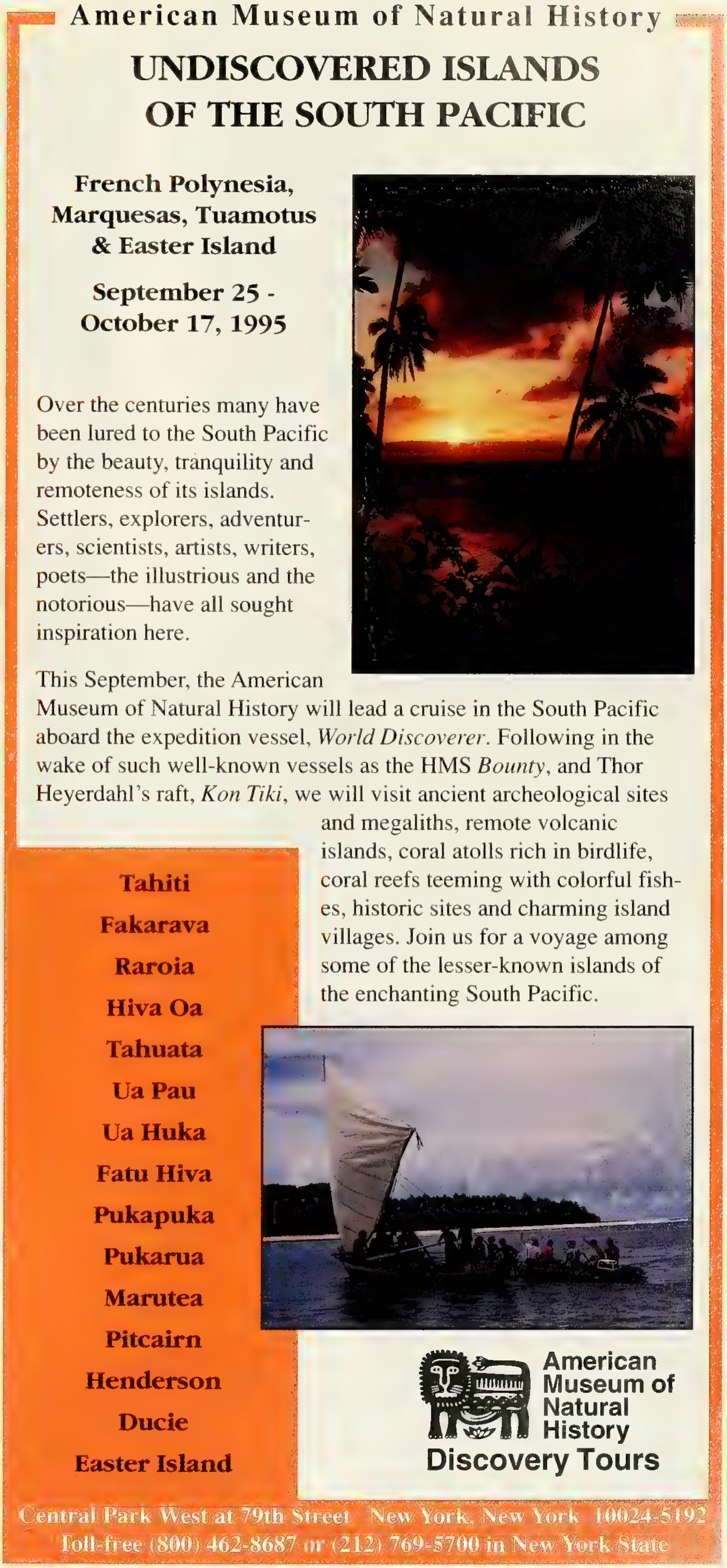
For **Catherine L. Craig** (page 32), spiders have never been something to fear. She insists that spiders are more afraid of humans than we are of them: "A spider's first impulse when something larger comes along is to stop moving and hope it goes away." Craig was originally attracted to spiders, and orb-weavers in particular, because of their bright colors, their diversity, and the beauty of their webs. A native of California, she completed her undergraduate degree at Stanford University, her master's degree at the University of California at Berkeley, and her Ph.D. at Cornell University. An associate professor of biology at Yale, Craig divides her time between that institution, where she maintains a living collection of tropical spiders in her laboratory, and the Smithsonian Institution's Tropical Research Station on Barro Colorado Island in Panama. For readers who want to learn more about webs, she recommends a book by H. W. Levi and L. R. Levi, *Spiders and their Kin* (New York: Golden Guide Series, Golden Press, 1969). Her favorite work of fiction, which gives very good accounts of how spiders weave their traps, is E. B. White's *Charlotte's Web* (New York: Harper and Row, 1952).

Taking a break from his desert fieldwork in Israel, **Joh R. Henschel** (page 36) tours sites in Jerusalem. Originally, Henschel's main scientific interest was underwater life, but after completing his master's degree in marine biology at the University of Cape Town in 1981, he developed a fascination for large mammals. In 1986 he completed his Ph.D. at the University of Pretoria, where he wrote his thesis on the socioecology of the spotted hyena. His interest sparked by a television documentary showing a wheel spider cartwheeling down the desert dunes, Henschel then embarked on another phase of his career. The next seven years were spent in the Namib, in fieldwork combining his interest in both deserts and spiders. Henschel is currently a zoologist at the University of Würzburg in Germany. When not in the field, he enjoys playing the violin and helping

As a zoology major at the University of Montana, **Paul J. Watson** (page 40) studied mostly vertebrate animals; he never expected to end up studying an arthropod, let alone a spider. In 1980, however, he took an animal behavior class with Allen Stokes at the University of Montana's Flathead Lake Biological Station. Students were asked to describe prey-handling behavior in the Sierra dome spiders that abound in the area, and Watson became hooked on the creatures. "I happened to throw a few flies into webs harboring both a male and female," he recalls, "and became intrigued by the

colleagues with computer problems. For those interested in why more animals have not evolved the ability to roll, Henschel recommends Stephen Jay Gould's "Kingdoms Without Wheels" (*Natural History*, March 1981).

intersexual conflict over prey, which the male usually got to eat. Naïvely, I had expected more chivalry from the male." That experience, and Stokes's encouragement, led Watson to complete a doctorate at Cornell University, where he studied the Sierra dome spider's sexual system and the reasons that females mate with several males. After more than a decade's work at the Flathead Lake Biological Station, Watson now teaches the animal behavior course there. He has also worked as a NATO postdoctoral fellow at Oxford's zoology department and is currently a research assistant professor at the University of New Mexico. Watson uses spiders to study such problems as how nonrandom mating of females affects the viability of offspring and how stress or malnutrition can generate asymmetry in animal bodies. For further information on the general biology and behavior of spiders, Watson recommends *Spider Communication: Mechanisms and Ecological Significance*, edited by Peter N. Witt and Jerome S. Rovner (Princeton: Princeton University Press, 1981).


American Museum of Natural History

UNDISCOVERED ISLANDS
OF THE SOUTH PACIFIC

**French Polynesia,
Marquesas, Tuamotus
& Easter Island**

**September 25 -
October 17, 1995**

Over the centuries many have been lured to the South Pacific by the beauty, tranquility and remoteness of its islands. Settlers, explorers, adventurers, scientists, artists, writers, poets—the illustrious and the notorious—have all sought inspiration here.

This September, the American Museum of Natural History will lead a cruise in the South Pacific aboard the expedition vessel, *World Discoverer*. Following in the wake of such well-known vessels as the HMS *Bounty*, and Thor Heyerdahl's raft, *Kon Tiki*, we will visit ancient archeological sites and megaliths, remote volcanic islands, coral atolls rich in birdlife, coral reefs teeming with colorful fishes, historic sites and charming island villages. Join us for a voyage among some of the lesser-known islands of the enchanting South Pacific.

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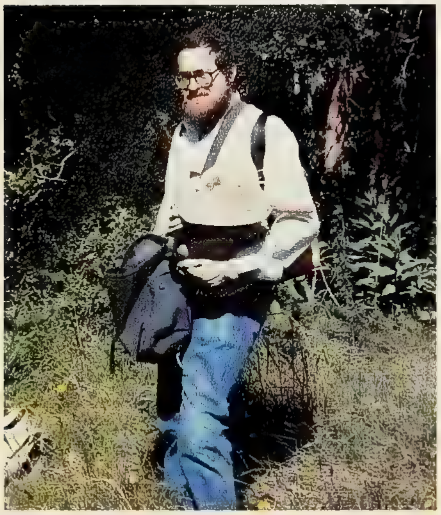
Photographed while collecting spiders in Chile, **Norman Platnick** (page 50) became an arachnophile as an undergraduate in a small college in southern West Virginia. There he met his wife, Nancy, who was interested in millipedes, and the two collected arthropods extensively in the Appalachian Mountains. But Platnick usually returned to the lab with far more spiders than millipedes; he got interested in trying to identify them and somehow never stopped. He earned his Ph.D. from Harvard University's Museum of Comparative Zoology and has been a curator in the American Museum's entomology department for more than two decades. His fieldwork, concentrated on South Temperate Zone faunas—especially those of Chile and New Caledonia—is reflected in his 220-some publications on spider systematics, phylogenetics, and biogeography. As an adjunct professor at Cornell and the City University of New York, he advises a coterie of graduate students from Wales, China, Sri Lanka, and Peru.



Simon Pollard (page 44) attributes his fascination with spiders to a well-developed sense of the macabre. In the field and laboratory, he loves to catch these arachnids eating—the very behavior that gives them their bad name. After earning his M.S. and Ph.D. from the University of Canterbury, in Christchurch, New Zealand, Pollard completed postdoctoral fellowships at the University of Virginia and the University of Alberta. He is now back in New Zealand at the University of Canterbury doing research on spider feeding mechanisms and secondary sexual traits in jumping spiders. On occasional trips to North America, he likes to take detours to Southeast Asia to collect and photograph rain forest spiders. On one of his recent forays, he stopped off in the Philippines to photograph the jumping spiders that accompany his article. Pollard is scheduled to give a slide-illustrated talk at the American Museum on Tuesday, March 21, at 7:00 P.M.

Ilse Köhler-Rollefson (page 54) had her first close encounters with camels in 1979, while doing archeological fieldwork in Jordan. Soon thereafter she received a degree of doctor of veterinary medicine from the Veterinary College of Hanover, Germany, and in 1990 began researching camel pastoralism, first in the Sudan and then among the Raikas in India. Her photograph, which shows her with her camel, Mira, was taken by portrait photographer S. L. Raika. Köhler-Rollefson, whose permanent residence is in Ober-Ramstadt, Germany, is currently a Humboldt Research Fellow at Jodhpur University, India. She is the founder and president of the League for Pastoral Peoples, an advocacy and support organization for pastoralists worldwide. For additional reading, she recommends *The Camel: Its Evolution, Behavior, and Relationship to Man,* by Hilde Gauthier-Pilters and Anne I. Dagg (Chicago: University of Chicago Press, 1981); "Wandering with India's Rabari," by Robyn Davidson (*National Geographic,* September 1993); and *The World of Pastoralism: Herding Systems in Comparative Perspective,* edited by John G. Galaty and Douglas L. Johnson (New York: Guilford Publications, 1990).

After twenty-three years as an elementary-school teacher in New York City, **Arthur Morris** (page 84) became a full-time freelance photographer and headed to Florida to pursue his new career and favorite subjects, birds. This month's "Natural Moment" was taken at the Venice rookery, a renowned spot among Florida nature photographers. Situated near a highway and a shopping area, the site still attracts waders, like the great blue herons pictured on their nest. Morris is the founder of the organization Birds As Art/Instructional Photo Tours. For years, Morris brought his slides of birds into the classroom, and he has designed innovative nature programs for children. He is the author of *Bird Photography Basics,* a how-to booklet published by Bird Watcher's Digest Press. Morris says that there is "nothing complicated" about his approach to nature photography. "I shoot only wild, free, and unrestrained birds without flashes, filters, or set-ups." For the photograph of the great blue herons, he used a Canon T-90 body, an 800 mm lens, and Fuji Velvia film pushed one stop.

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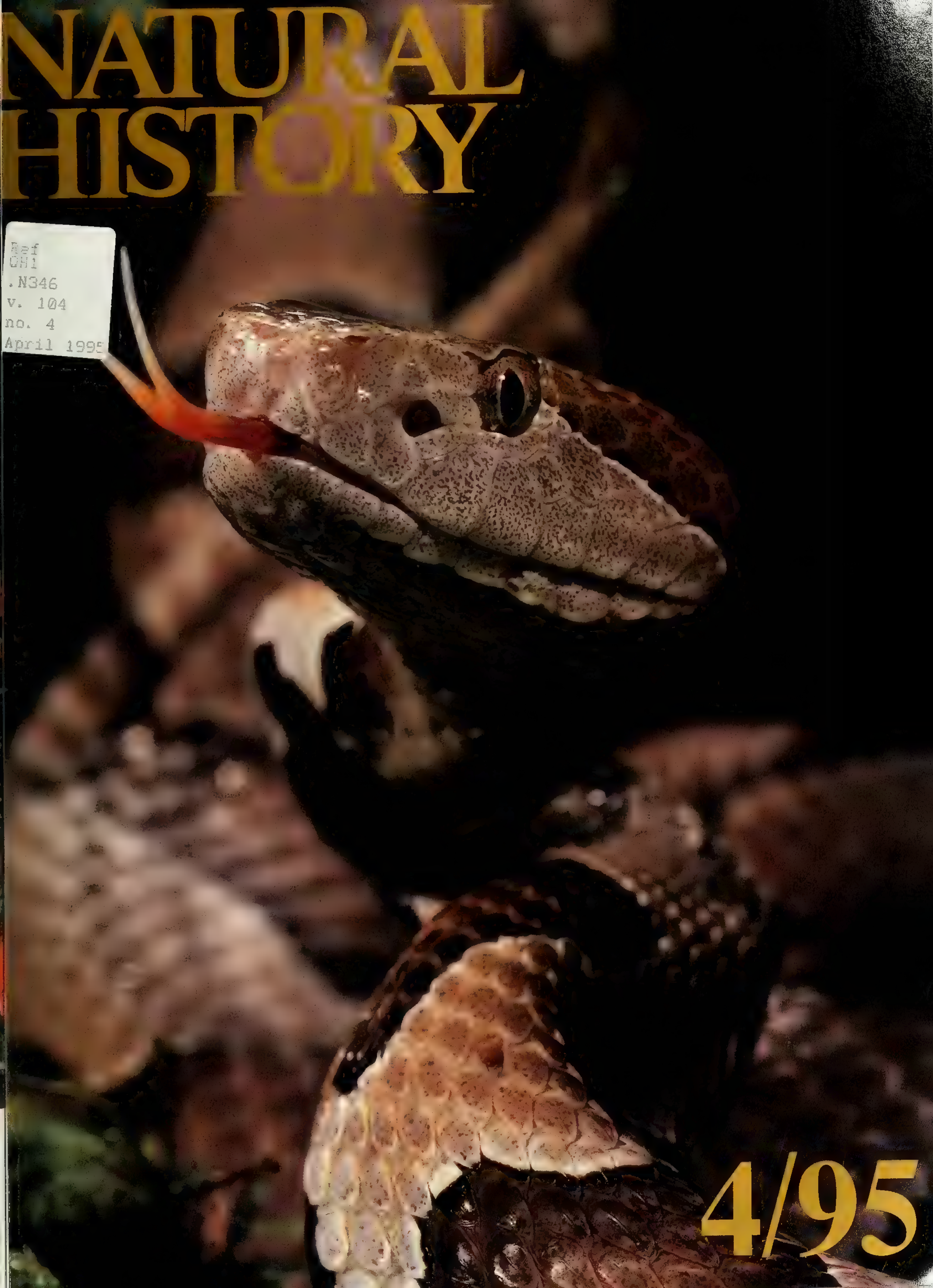

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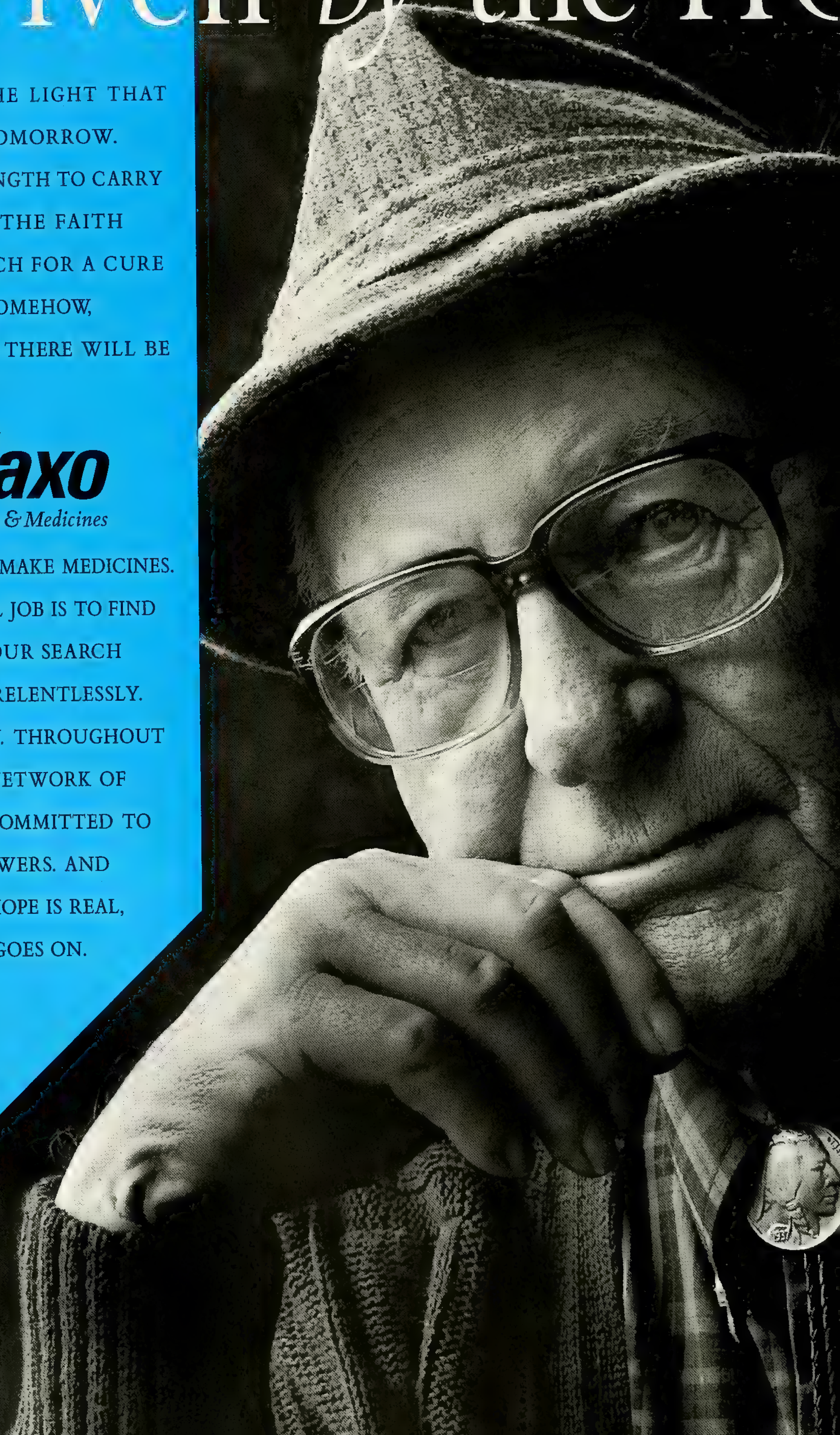

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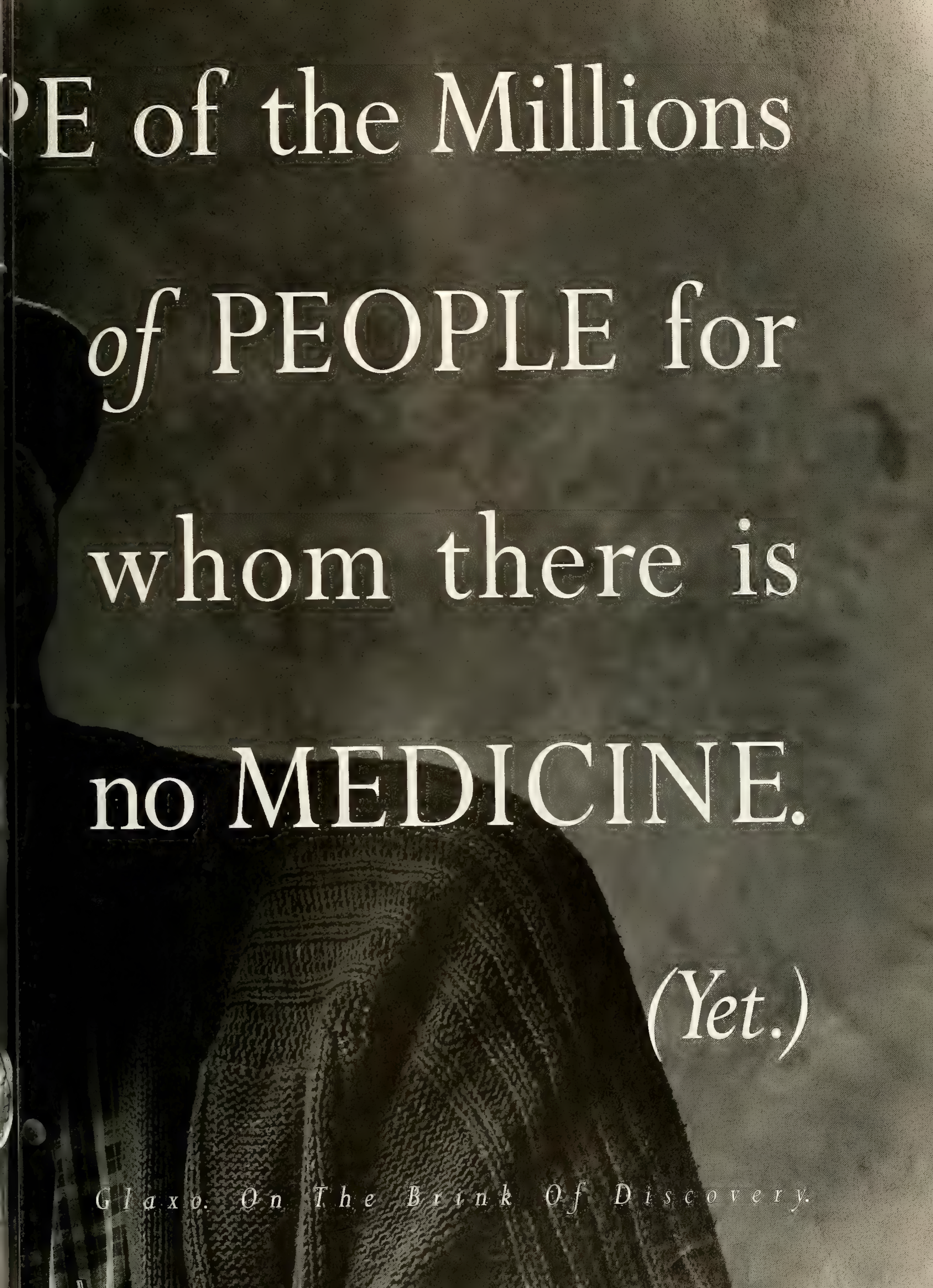
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COVER: A southern copperhead extends its forked tongue, a two-pronged instrument that is vital for tracking prey. Story on page 48.
Photograph by Joe McDonald.

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Return to Nuku Hiva

As a Pacific island leaps into the future, archeologists probe its past

by Robert C. Suggs

The passenger freighter drops anchor in the calm bay of the Taipivai valley, on the southeast corner of Nuku Hiva, a rugged volcanic island in the Marquesas archipelago of eastern Polynesia. With its cliff-walled valleys and bristling peaks and ridges, this island was home to me during two visits between 1956 and 1958, when I carried out archeological excavations for the American Museum of Natural History. I had hoped to return sooner, but this is my first trip back, this time as a consultant to an international archeological team that is beginning new excavations at a beach site that I discovered years earlier. Once more we'll dig beneath the dune for answers to our questions about how and when prehistoric seafarers explored and settled the far-flung islands of the Pacific.

The world of Polynesian archeology has made great advances since 1958, but they are nothing compared with the changes in Marquesan daily life. Progress in interisland transportation tells the story. In 1958, my wife and I left Nuku Hiva aboard the *Tiare Taporo,* a venerable, 113-foot wooden copra schooner that sailed the Tahiti–Marquesas run for half a century. Skippered by the late Louis Tapotofarerani, it followed a mutable and totally secret schedule. Passengers, livestock, and cargo jostled for space on the ship's worn decks. By contrast, the *Aranui,* which now brings our advance party and equipment to Nuku Hiva, is a sturdy, steel, German-built 345-foot passenger freighter, whose two expert Polynesian captains make use of satellite navigation gear. The *Aranui* carries passengers and crew in air-conditioned comfort (although locals still prefer to sleep on the afterdeck), has excellent cuisine, and employs a staff of well-educated, multilingual hostesses who serve as guides for excursions ashore. A fine little library on Polynesian archeology and anthropology is maintained for passengers' reference. In addition to delivering passengers, cargo, and tourists, the regularly scheduled *Aranui* has opened up the entire Marquesas archipelago to the influences of the outside world. As an extra benefit, doctors and nurses accompanying the cruises often provide medical assistance to inhabitants of remote valleys.

We board a thirty-foot whaleboat and head for shore. Beside me sits a friend and former star of my digging crew, Hu'uveu Teikitekahioho, who has since risen to become assistant cargo master on the *Aranui.* As we slide into the dock,

On Nuku Hiva's north coast, volcanic peaks overlook Hatiheu valley.

Anna E. Zuckerman; Envision

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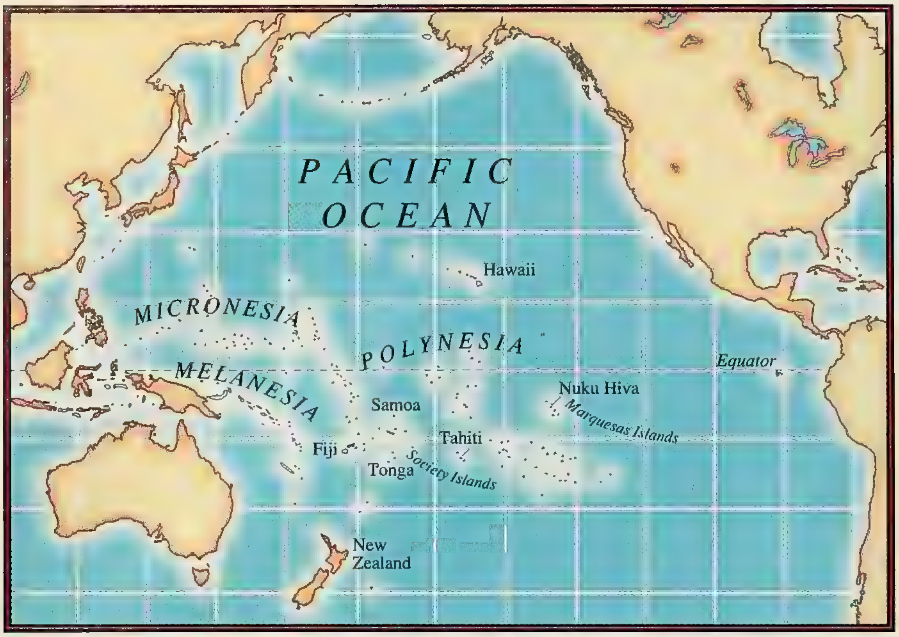


Joe LeMonnier

Hu'uveu points out the head of my welcoming committee, a hefty, red-headed Marquesan: "That's Pukiki." When I last saw him, Pukiki ("Red") Vaia'anui was a quiet, contemplative three-year-old; now he's a 220-pound French Marine veteran, Taipivai valley's police officer, and a prosperous storekeeper. He's brought other members of the family that hosted my wife and me for several months so many years ago, including a sister who, at the age of about nine, was the desperately unwilling subject of my only fling in the area of emergency dental surgery (the extraction was successful). After thirty-five years, she has finally forgiven me!

While other members of the team store our gear, Pukiki and I bump up the valley in his big truck to visit another sister, Henriette Ta'aviri, with whom we'll stay for a few days. In 1958, horses were the main form of transportation, and the only motor vehicle in Taipivai valley was a broken-down World War II jeep that only ran in second gear—if it ran at all. Now the area is filled with powerful trucks. More innovations appear up the valley road: a neat mayor's office and a modern post office, complete with pay phones operated by "smart cards" that link Nuku Hiva via satellite to the entire world.

For a few days we roam the dense bush of the Taipivai valley, exploring some of the sites that I excavated in the 1950s. During the frequent downpours, we watch French-dubbed *Dynasty* and *The Simpsons* on Henriette's satellite TV and eat like (Marquesan) kings. I soon become aware that I'm no longer on good terms with the coconut cream used as a standard sauce on virtually all foods, but by that time the team leaders have arrived from Tahiti, landing at Nuku Hiva's new airstrip. They are Barry Rolett, of the University of Hawaii, and Eric Conte, of Tahiti's French University of the Pacific. (In 1958, aircraft had appeared only three times in Nuku Hiva's history; now Air Tahiti flies a twice-a-week schedule.)

On the trucks again, we make our way up the Taipivai valley, go through the pass over Nuku Hiva's east–west volcanic spine, and descend into the north coast valley of Hatiheu. On foot, we scale another ridge and reach our base, a well-appointed missionary youth camp on the shores of the Anaho valley.

Along the way, Marquesan friends constantly ask whether I'm still married to the same person. Affirmation evokes disbelief (Marquesan marriages are pretty fragile), then disappointment: Why didn't you bring her? My wife, Rae, a registered nurse who accompanied me in 1957 and 1958, is still revered for the medical care that she provided to the populations of several of Nuku Hiva's remote valleys. I promise to bring her next year. After determining my marital status, it's time to engage in procreational prestige games: How many kids? My three cannot compete with the twenty-plus offspring of many Marquesan males.

From our base camp in Anaho valley, it's just a half-hour hike over a low ridge to my old beach site in Ha'atuatua valley, on Nuku Hiva's uninhabited northeastern tip. From the crest, the familiar path meanders among the mudholes, roots, and fallen tree trunks of the shady hibiscus grove that covers the western end of Ha'atuatua valley. I descended this path for the first time in 1956, following up on a tip from a Marquesan, who told me that a tidal wave in the late 1940s had exposed "pig bones" in the face of the Ha'atuatua beach dune. At the end of the path, much more than pig bones awaited: the wave had cut into the edge of a huge archeological site, which extended along the entire 800-yard length of the beach and, as we later found, 550 yards back to the hibiscus grove.

The windblown dune face was littered with the debris of ancient habitation. Ruins of a ceremonial structure, with pavements and burials (the "pig bones"), lay in the central dune, surrounded by remains of dwellings. This was an archeologist's dream: an opportunity to study both the material and spiritual sides of ancient Marquesan culture and to collect a sample of prehistoric Marquesan skeletal remains. The bones were of great interest to my mentor at the American Museum, the late Harry L. Shapiro, who joined me briefly at Ha'atuatua in 1956.

Among the artifacts I recovered were beautiful mother-of-pearl fishhooks of various shapes and sizes; stone flake tools, triangular coral files and sea urchin spine files used to shape and polish these hooks; stone adzes of various types and sizes; and coral rubbing stones for wood finishing. The Polynesians also used wood and vegetable fiber, which had decayed in open sites like Ha'atuatua but survived in bone-dry guano caves on the arid west coast of Nuku Hiva, where excavations produced mats, nets, fishing lines, loincloths, and drinking gourds. Theirs was a remarkable maritime culture that exploited not only the ocean's resources but also domestic animals (pigs, dogs, and chickens) and such transportable root and tree crops as breadfruit and yams.

Emerging from the grove into the brilliant morning sunlight of the dune, I look again at what must be one of the most beautiful archeological sites in the world. Ha'atuatua's gently curving beach, beaten by trade-wind-driven surf, is wedged in between steep, rocky cliffs and ridges. These cliffs probably gave Ha'atuatua its name in Marquesan: *ha'a* means "bay" and *tuatua* means "sharp ridge"—Sharp Ridge Bay. The flat, conical bulk of Ua Huka Island floats on the eastern horizon. Picturesque it may be, but the Ha'atuatua dune also swarms with clouds of tiny, blood-sucking *nono* flies, which enthusiastically and immediately welcome me back. It's probably been a long time since they dined on Old Yankee.

The results of my early excavations at

Exposed by a tidal wave in the 1940s, an archeological site in Ha'atuatua valley revealed an ancient Marquesan maritime society.
Danee Hazama

Ha'atuatua were exciting, at least to those who believed that eastern Polynesia, the Marquesas in particular, had only been inhabited for a few centuries. Carbon-14 samples collected from deep beneath the pavement in the ceremonial area and from the northern habitation area gave dates of 2,225 and 1,850 years ago, respectively. Another set of samples produced dates between 1,300 and 1,000 years ago. In the remains of a structure in the ceremonial area we also recovered several potsherds from well-made pots—the first prehistoric pottery found in eastern Polynesia. Subsequent analysis of these shards revealed that while some may have been made from local clay, others contained minerals suggesting an origin in Fiji, in eastern Melanesia, 3,000 miles to the west. The voluminous Ha'atuatua artifact collection included a group of adzes, ornaments, and scrapers that also seemed to display western Polynesian or Melanesian influence, if not origin.

The early dates and artifacts with western Polynesian or Melanesian characteristics seemed to indicate the possibility of direct contact with, or settlement from, the west. This was heresy in some quarters of the archeological community, where concerns for "turf" resemble those of a typical street gang. Previously, it had been assumed that about 1,000 years ago, people from western Polynesia colonized a single eastern Polynesian homeland. This homeland, the Hawaiki of their legends, was generally believed to have been Tahiti, or the Society archipelago. From there they were thought to have settled the rest of eastern Polynesia. Evidence of early settlement in the Marquesas called these assumptions into question. Were the Marquesas, rather than Tahiti, the "real" eastern homeland, or were there at least two eastern homelands?

Thirty-five years of fieldwork in Polynesia has provided substantial support for Nuku Hiva's early dates—without muting the controversy. Today we know that the ancestors of the Polynesians arrived in the islands of eastern Melanesia about 3,600 years ago and were established in the Fiji–Samoa–Tonga region by about 3,200 years ago. Their characteristic decorated pottery is known as Lapita ware, named after the Melanesian site where it was first described. Possibly, some of these people soon began to explore eastern Polynesia. Considered against this firm chronological framework, the early Ha'atuatua dates aren't unusual. Subsequent digs in the Marquesas have produced additional early dates, from 2,150 to 1,700 years ago, to bolster those from Ha'atuatua.

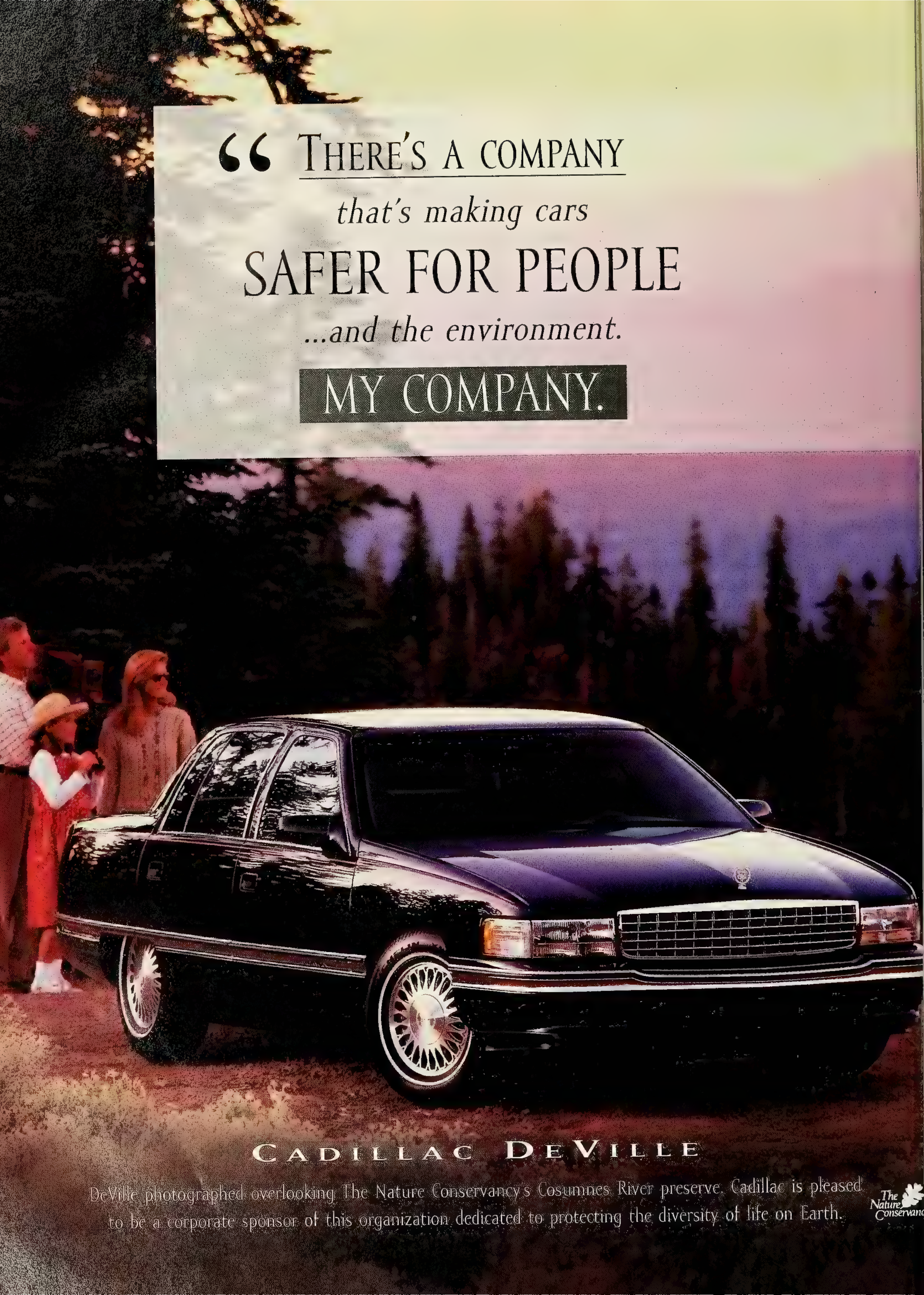
As we mill around on the Ha'atuatua dune, feeding the *nono,* laying out our grid, and opening our initial test pits, we are mainly concerned with the details of how the first pioneers made their final moves to eastern Polynesia. As the days pass, we find and open my old trenches, correlate them with our many new test pits, expose a large section of midden (refuse) for minutely controlled excavations, and make stratigraphic cuts in the faces of riverbanks that cut through the site. We search unsuccessfully for additional reddish potsherds, but we recover many other interesting artifacts: a harpoon made of a human leg bone, adzes, fish hooks in many stages of manufacture, and debris from the manufacture of stone tools. The stone debris includes possibly exotic material—black obsidian, phonolite (a greenish volcanic stone), and yellowish chert. Although many of our excavations go down as much as six feet, we continue to find bird bones and stone flakes.

In the evenings, we straggle back to our Anaho camp, which is presided over by Te Hono ("Mom"), a little woman whose radiant smile cloaks an ability to control large Marquesan males with a mere glance. Dehydrated, we swill ice water with flavored sugar syrup and gorge on Mom's latest pastries, before cleaning up for her dinner.

Today, as in the fifties, Marquesans' acquaintance with their own past comes mainly through legends. They know little about archeological findings, but are eager to learn, and I get excellent questions when I lecture the fifth and sixth grades in Hatiheu school. They even want me to explain the carbon-14 dating method. We enlist the help of some pupils in our laboratory work.

After six weeks our excavation season is over (two more seasons are planned). On July 14—Bastille Day—we pack our gear in last-minute chaos and set out on a chartered dive boat for Taioha'e, Nuku Hiva's main valley, to begin the long trip home. We won't know for a while what we've contributed to answering the "how" question of eastern Polynesian settlement because the mass of data and artifacts collected require detailed study. We suspect that the settlement of Polynesia may be more complicated than anyone has assumed, with both eastern and western Polynesians sailing helter-skelter, for various reasons, all over for many centuries. In such a situation, trying to identify homelands, or even a homeland area, may be hopeless, and may distract from the more important work of tracing more fine-grained trade or migratory connections. But Ha'atuatua surely holds some of the answers, and we look forward to unlocking more secrets buried in the dune.

Robert C. Suggs's earlier experiences in Nuku Hiva are chronicled in numerous books and articles, including Hidden Worlds of Polynesia. *He lives in Alexandria, Virginia.*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Left Snails and Right Minds

Were early conchologists choosing sides when they held the mirror up to nature?

by Stephen Jay Gould

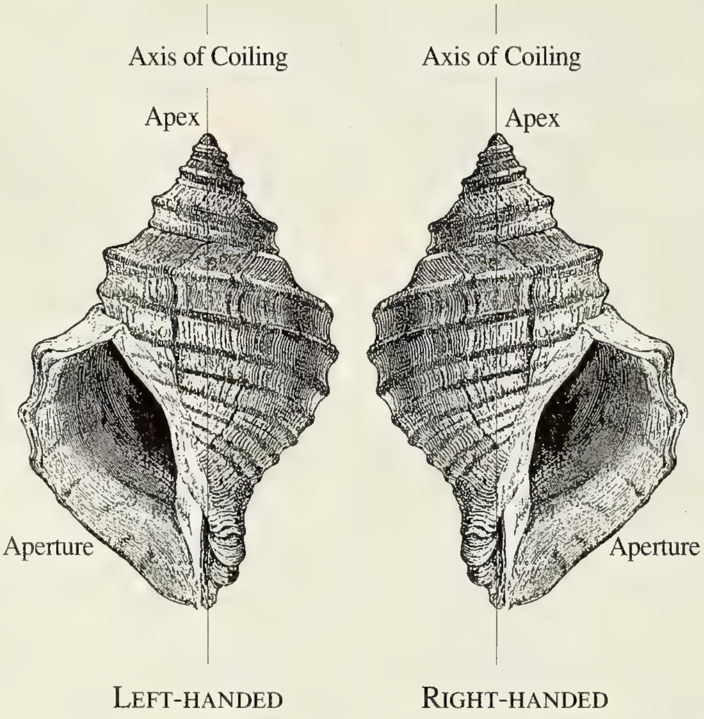
What immortal hand or eye
Could frame thy fearful symmetry?

William Blake's familiar inquiry about the creation of tigers raises a vital question that we may pose literally, although the poet's intention may have been more metaphorical. Why does symmetry, particularly our own bilateral style of mirror images around a central axis, predominate among animals of complex anatomical design? Why do we come in equivalent right and left halves? And why do we get so fascinated by the minor departures, usually more of function than overt form, that loom so large in our culture: the predominance of right-handedness and the difference between "right" and "left" brains?

A few major groups of organisms do not present a basically bilateral symmetry, including my own favorite subject for research, the gastropods, or snails. The soft body of a snail is tolerably bilateral when pulled from the shell and stretched out, but the animal houses this body in a shell built by winding a tube in one direction around an axis of coiling. The snail shell may therefore be the most familiar nonbilateral form among "higher" animals.

A tube can be wound around a vertical axis in either of two directions, designated as right- and left-handed. If we hold a snail in our conventional position, with the apex at the top and the aperture (or opening for the body) at the bottom, then we call the direction of coiling right-handed if the aperture lies to the right of the axis of coiling when we view the specimen face to face, and left-handed if the aperture lies to the left of the axis of coiling. (All this should be much clearer in the illustration below than in any words I can supply.)

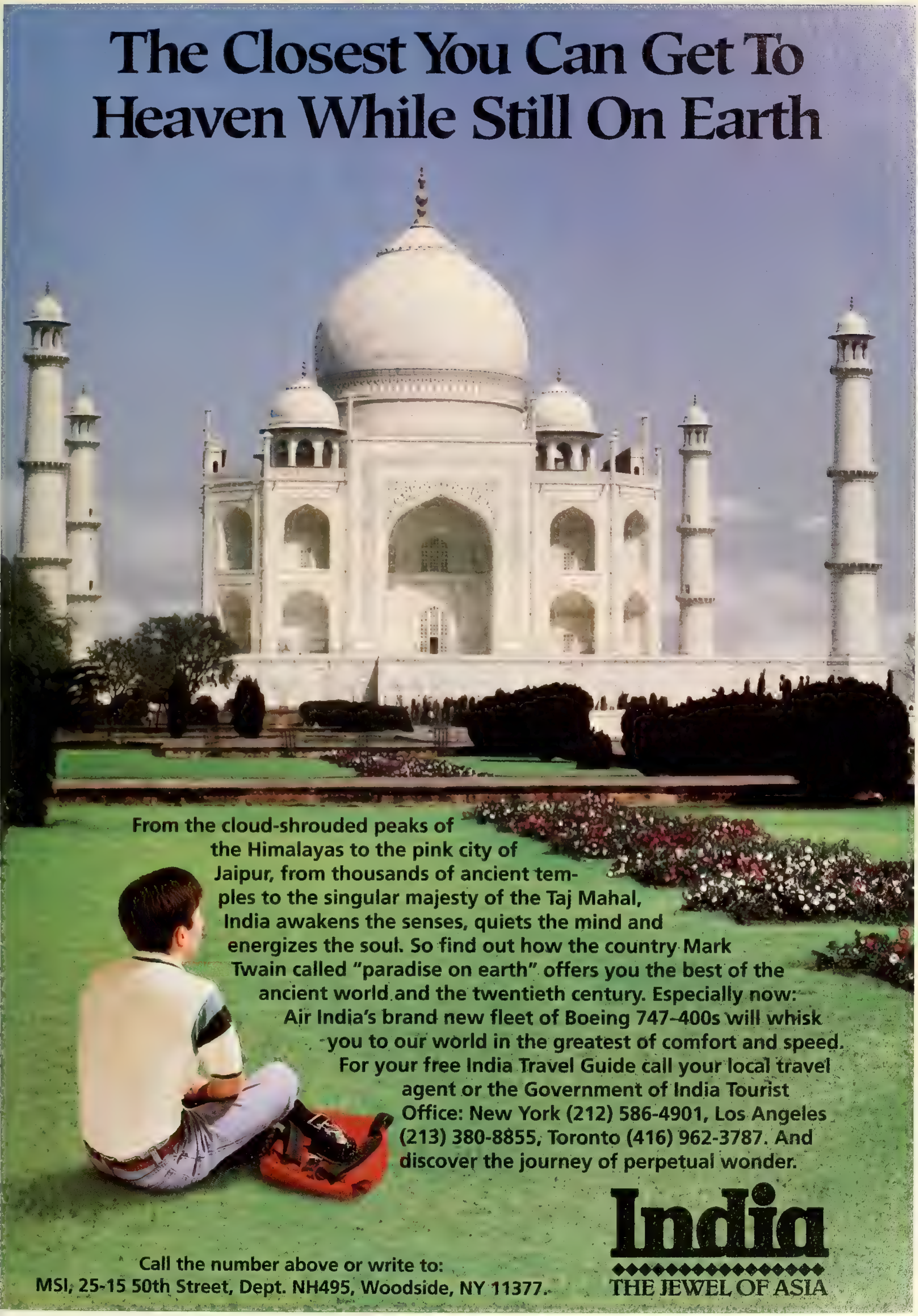
But this naming is truly arbitrary, for snails know nothing about apex up and aperture down (in life, most snails carry their shells more or less horizontal to the ground). If we draw the specimen apex down (as French scientific illustrators have always done), then the apertures of right-handed specimens open to the left of the axis of coiling.



LEFT-HANDED RIGHT-HANDED

In India, for example, the conch shell *Turbinella pyrum* is venerated as a symbol of Vishnu. (In the *Bhagavad-Gita,* Vishnu, in the form of his most celebrated avatar, Krishna, blows his sacred conch shell to call the army of Arjuna into battle.) The exceedingly rare left-handed specimens of this shell are particularly treasured and used to sell for their weight in gold. But Hindus interpret the apex as the bottom of the shell and therefore call this rare form right-handed. Perhaps they treasure these rare shells because only these specimens, in the Indian version of an arbitrary decision, match the style of dominant handedness in human beings (and, I suppose, anthropomorphic deities).

A purist might forgive snails for departure from the bilateral paradigm if only they honored an even more inclusive symmetry by growing right- and left-handed spirals in equal numbers. But snails remain twisted and awry on this criterion as well—for right-handed shells vastly outnumber lefties not only in the sacred conch of India but in virtually all species and groups. Right-handed shells are called dextral, from the Latin *dexter,* meaning "right," and memorialized in our language by a host of prejudicial terms invented by the right-handed majority to honor their predominance. Right is dexterous, not to mention "correct" in many languages—awright buddy. The law, by

The Closest You Can Get To Heaven While Still On Earth

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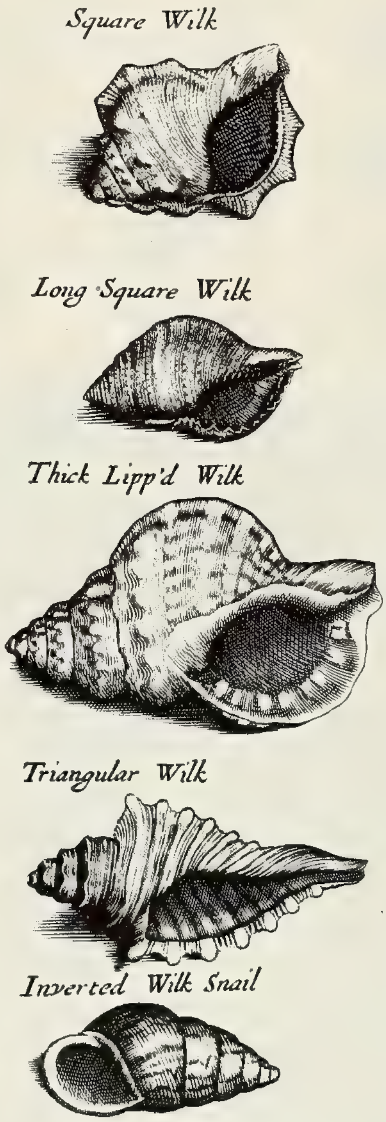
the way, is *droit* in French and *Recht* in German, both meaning "right." (The language police will never regulate these essays, but it remains fair and historically interesting to point out that the "rights of man," noble as the sentiment may be, embody two linguistic prejudices of unfairly dominant groups.) Left-handed shells are called sinistral, from the Latin *sinister,* meaning "left"—also denigrated in our languages as sinister or *gauche,* a French lefty. I shall, for the rest of the essay, use this terminology by calling right-handed shells dextral, and lefties sinistral. I also can't help wondering if we didn't make our initial arbitrary decision to call a snail's apex "up" because this orientation would then allow us to designate this overwhelmingly more common direction of coiling as "right."

The vast majority of forms grow a dextral shell, although a few sinistral specimens have been found in most species. For example, in *Cerion,* the West Indian land snail that forms the subject of my own technical research, only six sinistral specimens have ever been found, out of millions examined (while, as stated above, a lefty *Turbinella* in India was literally worth its weight in gold). A few species grow exclusively or predominantly sinistral shells, but related species of the same group are usually dextral. We often exact a price from these rare sinistrals by giving them names to match their apostasy—as in *Busycon contrarium* or *B. perversum,* the technical monikers variously awarded to the most common sinistral species of northern Atlantic waters. A few groups of species (notably the family Clausiliidae) are predominantly sinistral but, again, all closely related lineages are dextral. In short, dextral snails greatly predominate (at a far higher frequency than human righties versus lefties) at all levels: individuals within a species, species within a lineage, and lineages within larger groups.

At this point, astute and inquisitive readers will be asking the obvious questions, "Why? What conceivable advantage does dextrality hold over coiling in the other direction?" I can only report that these inquiries are both appropriate and fascinating—and that we don't have a clue about the answers. (I would not even assume that the questions should be posed in terms of putative advantages. The two modes might be entirely equivalent in functional terms, with dominant dextrality only a historical legacy of what happened to arise first.) I'm sorry to wimp out on such interesting questions, but I can at least quote, on the same subject and to the same point, that greatest of all prose stylists in natural history, D'Arcy Wentworth Thompson (from his book *On Growth and Form,* first published in 1917 and still vigorously in print): "But why, in the general run of shells, all the world over, in the past and in the present, one direction of twist is so overwhelmingly commoner than the other, no man knows."

This essay, instead, shall take another turning on the subject of directionality in coiling—namely, the history of illustrations for snail shells in zoological treatises. Let me begin with a figure that I first considered both anomalous and amusingly in error. The plate reproduced below is from a famous work in natural history, published in 1681 by one of Britain's finest physicians and zoologists, Nehemiah Grew: *Musaeum Regalis Societatis, or a description of the natural and artificial rarities belonging to the Royal Society, whereunto is subjoyned the comparative anatomy of stomachs and guts.* (They did love long titles back then, and we will ignore the appendix, with its remarkable illustrations of vertebrate intestines, all stretched out and circling the pages.)



In an illustration from Nehemiah Grew's 1681 volume, only the bottom snail is shown coiling to the right.
AMNH

Note that all but one of these shells are sinistral in Grew's engraving. The exception, shown at the bottom, is conventionally dextral. Has the world turned? Those shells are labeled "wilk," or "whelk" in our modern spelling (a common name for conchlike shells)—and nearly all whelks are dextral, including the species shown here. The exception, drawn dextrally, gives the story away by the name imprinted above: "Inverted Wilk Snail." In other words, the shell labeled "inverted" is, in life, a rare sinistral named according to an old tradition for derogatory designation of the unusual. (At least "inverted" seems milder than "perverted," as in *Busycon perversum.*)

Obviously, Grew printed his snails in mirror image from their actual constitution. I initially assumed that Grew had committed a simple error and laughed at his fellowship with snail men throughout the history of illustration, for we are still making the same mistake today. In the current version, an offspring of modern technology, a snail may appear with reversed coiling because the photograph has been made from a negative inadvertently turned over before printing. Any expert paying explicit attention will notice the error, but we fallible mortals often let something this global slip by—for a reversed snail doesn't look grievously wrong if you don't have your eye and mind directly attuned to the issue of symmetry.

Any professional snail man can give you his list of embarrassments in this category. A dear late colleague, one of the world's leading experts on snails, published a beautiful wraparound dust jacket photo of reversed shells for the cover of his popular book. I must also admit (and how wonderfully unburdening after all these years of hiding such a shameful secret) that my own first publication on snails included several photographs of a newly discovered protoconch (embryonic shell) of an important genus—all published from reversed negatives. (I received the sweetest and most diplomatic letter from a colleague asking me if these dex-

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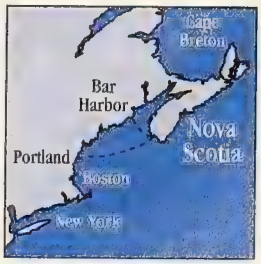

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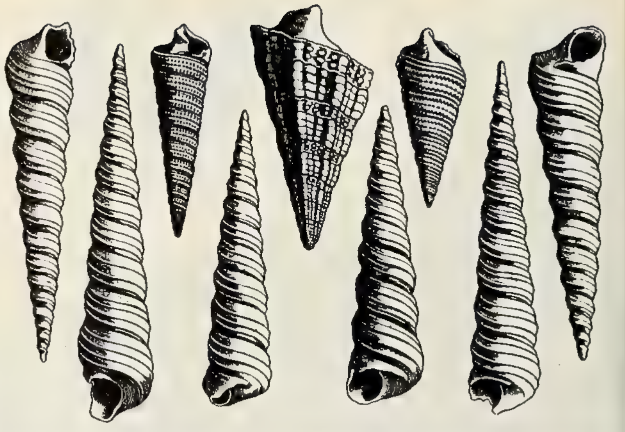
tral shells really had sinistral protoconchs and urging me to publish separately on such an important finding, or suggesting that maybe, just maybe, I had made the old error of reversed printing.) Baseball players make a proper distinction between physical errors, which can happen to anyone anytime and should engender no shame, and mental errors—bonehead judgments, forgetting the rules—which should never occur. Ordinary and honorable errors of fact are unavoidable in science, a field that thrives on self-correction, and properly defines its own progress by such improvement. I have never written an essay, and never will, without this analogue of a physical error. But printing a snail backward is a mental error. No excuses possible.

So much for my first thoughts about Grew's mistake. But as soon as I remembered a scholar's first obligation—to drag oneself from judgment within a smug present, considered better, and to place oneself, so far as possible, into the life and times of a person under consideration—I immediately realized that the issue could not be so simple. All media for printed illustration in pre-nineteenth-century treatises of natural history—woodblock printing, engraving on metal plates, lithography—require the initial production of an inverted image. That is, the engraver must carve a mirror image figure into his metal plate, so that the paper, placed atop the inked plate before pressing down to print, will receive the figure in proper orientation. Needless to say, all printers know this rule perfectly well; nothing could be more fundamental to their work.

Therefore, a printer who wants to engrave an ordinary dextral shell must carve a sinistral image upon his metal plate. Clearly, Grew's printer drew the snails onto his plate as he saw them, rather than reversed—and the result is an inverted image in the printed book: ordinary dextral snails look sinistral, and the lone sinistral looks like a conventional dextral.

But how did this happen? and why? This oddity cannot be the result of a simple fool's error of the baldest kind, for the engraver surely knew his rules and must have etched his letters and numbers in proper reversed order onto his plate, for all writing and numeration is correct in the printed version. Many scenarios suggest themselves, and we do not have enough evidence to decide: perhaps Grew supplied his printer with sketches already reversed but forgot to pass this information along; perhaps Grew provided all the sketches on a single sheet (without the words), and the printer then erred in pasting the sketch upon his plate recto rather than the proper verso. (I am assuming that engravers worked by affixing a sketch, drawn on transparent paper, directly onto their plate and then carving through.)



Dextral-coiling species are consistently shown as sinistral in a 1719 edition of Michele Mercati's Metallotheca.

But we should also consider a hypothesis of a fundamentally different kind. Perhaps we should not be so quick to assume, from our arrogant present, that these "primitives" of the seventeenth century must have been making an error at par with boo-boos still occasionally committed by modern photography. Perhaps the reversed shells of Grew's illustrations are not errors at all, but representations of a convention then followed and now abandoned.

I shall defend this more generous alternative in concluding my essay, but I had not considered this solution when I first saw Grew's plate about ten years ago. I simply stored this little "fact" away in my mental file of oddities in natural history. I must have labeled this item "Grew's funny mistake," for I never considered the possibility that reversed snails could be anything but an error, however committed.

As their primary virtue and utility, such mental files can lurk in the brain (wherever and however this remarkable organ stores such information) without disturbing one's thinking and planning in any manner. The files just hang around, waiting for some trigger to transport them into consciousness. (I would, for this reason, defend such ancient practices as rote learning for the basic chronology of human history and for reading the classics, particularly Shakespeare and the Bible, with a view to memorizing key passages.) I love antiquarian books in natural history, and my eyes do inevitably wander, for professional reasons, to pictures of snails. Thus, my "Grew mistake" file has been accessed quite a few times during the past decade. But I never had any project in mind, and I had devised the wrong preliminary conclusion about Grew's reversals. In fact, it took three or four random repetitions to make the subject explicit as a worthy topic, to force a revision of my own initial error, and to perceive the larger theme about science and human perception that could convert such a trivium (the depiction of snail coiling) into a decent subject for an essay.

A few years after my reading of Grew's book, I purchased a copy of my personal favorite among beautiful and important works in natural history, Michele Mercati's *Metallotheca*. Mercati (1541–1593), director of the Vatican botanical garden, also became curator of the papal collection of minerals and fossils organized under the aegis of the imperial pope Sixtus V, whose taxes impoverished the papal lands while building Rome in splendor. (I also love the man's name—the fifth instar of a guy named "six"; Sixtus I, a second-century figure, was the sixth bishop of Rome after Peter and took his name accordingly.) Mercati prepared a series of gorgeous engravings for a catalog of the Vatican collection, but this work never appeared in his lifetime (perhaps because Sixtus V died unexpectedly in 1590). But the plates hung around in the Vatican's vast storehouses for nearly a century and a half, until J. M. Lancisi finally published them, along with Mercati's text and many new engravings, in 1719 as the *Metallotheca*. (If a *bibliothèque* is a library, then a *metallothèque* is a collection of metals and other objects of the mineral kingdom.)

The *Metallotheca* contains numerous plates of fossil snails in a chapter called *Lapides Idiomorphoi* (or stones that look like living things—Mercati, along with many sixteenth-century scholars, did not interpret fossils as remains of organisms but as manifestations of "plastic forces" inherent in rocks). In all plates—so we are in the presence of a conscious generality, Discover some of nature's most surprising treasures

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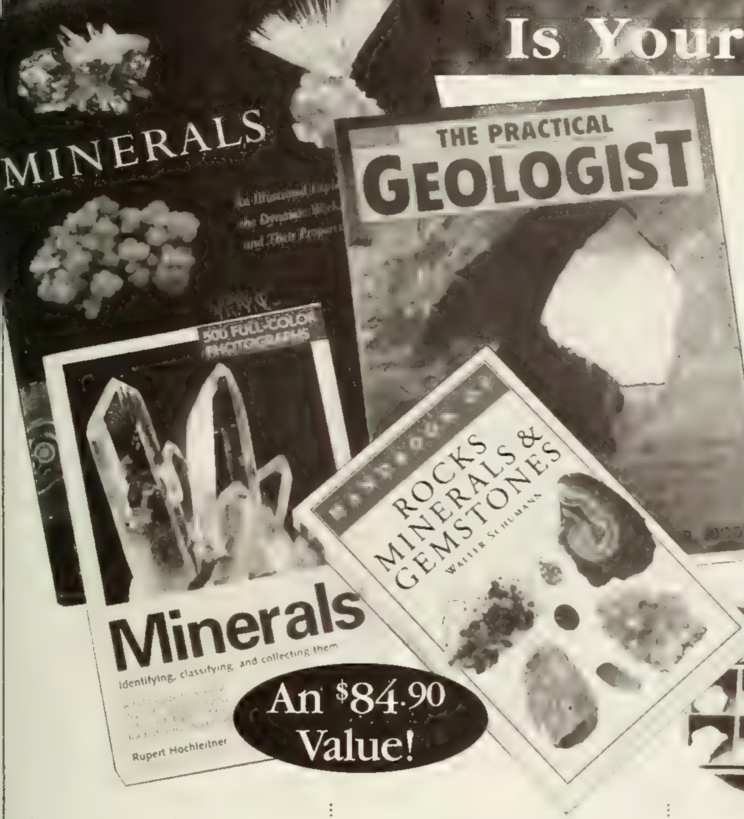
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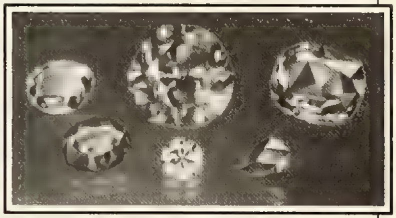

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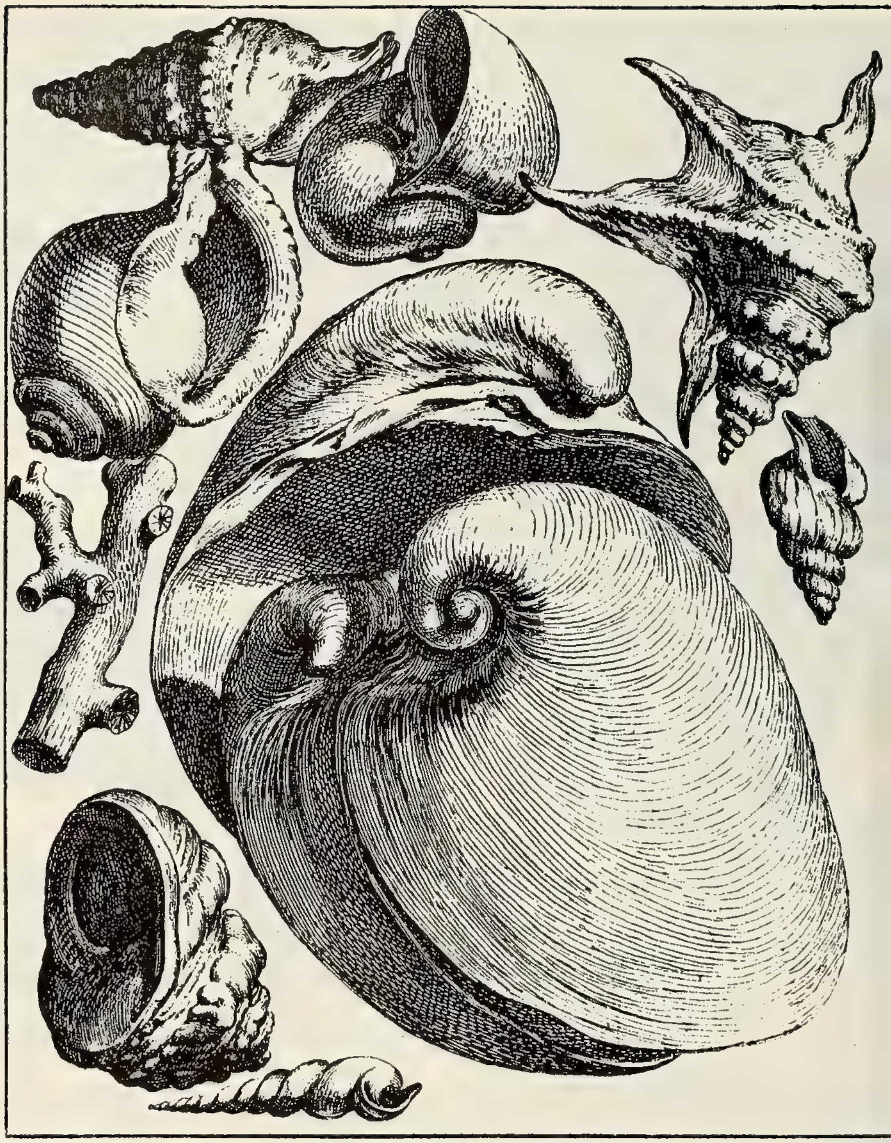
not an individual error—dextral snails appear as sinistral engravings.

But assumptions die hard, even if never founded on anything sensible. I couldn't call reversed printing a simple error any more, so I opted for the next line of defense within the bias of progress: I assumed that such indifference to nature's factuality must represent a curious archaicism of the bad old days (for Mercati goes way back to the sixteenth century)—and thus not worthy of much intellectual attention. Again, I stored the observation on the back shelves, in the stacks of my mentatheca.

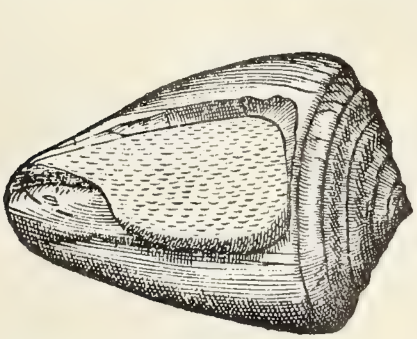
More random encounters since then have finally shaken up my false assumption, for I have noted sinistral illustrations of dextral shells again and again in works published before 1700. In fact, almost all snail illustrations from this period are reversed, so we must be observing a conscious convention, not an occasional error. By contrast, I have almost never seen a reversed illustration in works, say, from Linnaeus's time (early to mid-eighteenth century) onward, except as real and infrequent errors. Therefore, and interestingly, the obvious hypothesis that photography ushered in the change must be false. I simply do not know (but would dearly love to have the answer) why a convention of drawing snails in reversed coiling yielded to the conviction that we should depict them as we see them.

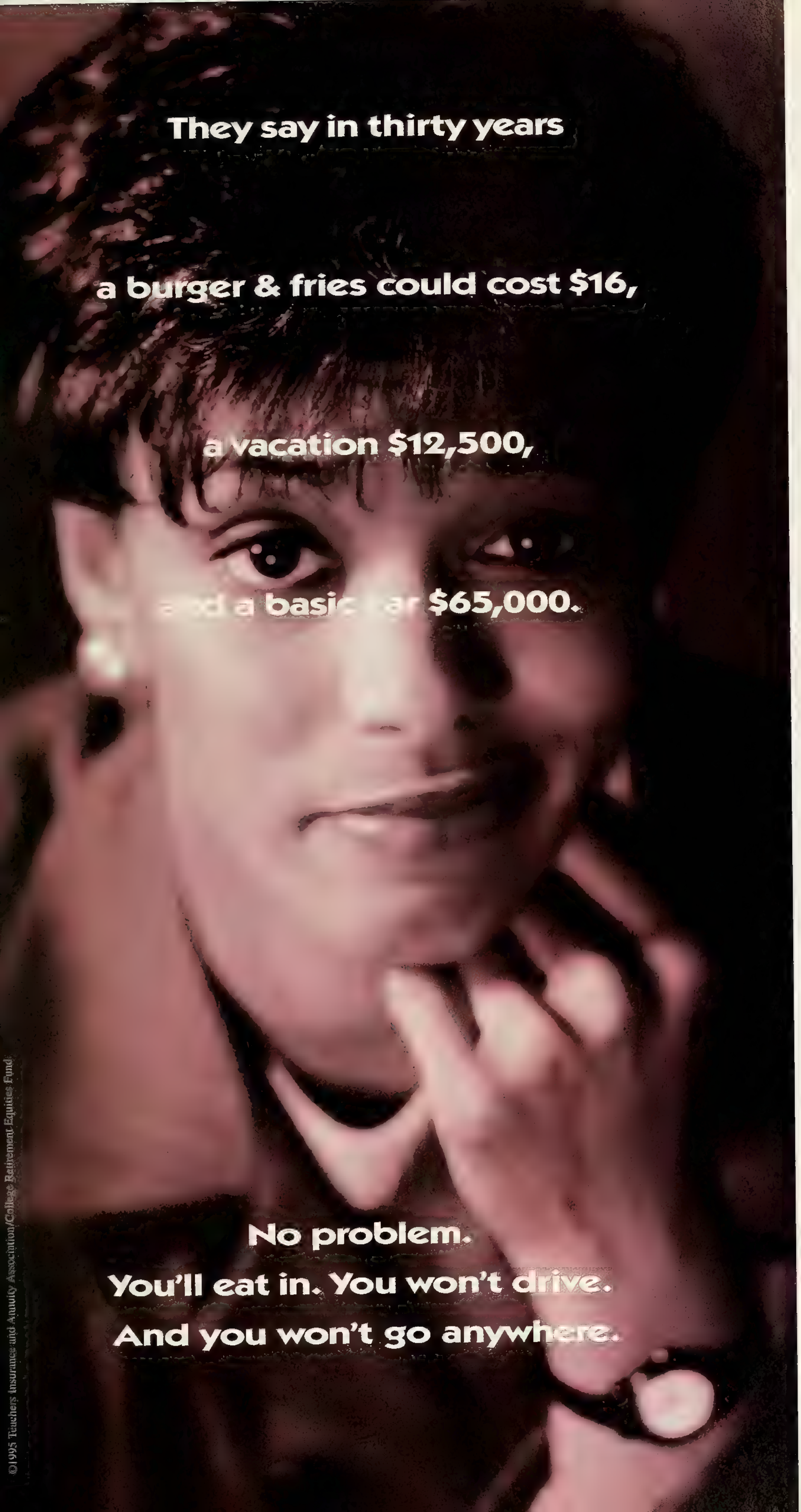

Dextral snail species are depicted with left-handed coiling in a volume on fossil snails by seventeenth-century paleontologist Augustino Scilla.

To shorten my chronicles of personal discovery, two further examples finally convinced me that older illustrations had drawn snails with reversed coiling on purpose. I first consulted as close to an "official" source as the sixteenth century can provide—the *Musaeum Metallicum* (another account of a major fossil and rock collection) by the Italian naturalist Ulisse Aldrovandi (1522–1605), who, in competition with his Swiss colleague Konrad Gesner (1516–1565), wrote the great compendia that pulled together all available knowledge about animals—ancient and modern, story and observation, myth and reality, human use and natural occurrences. My edition of Aldrovandi's posthumous work on fossils dates from 1648 and illustrates all snails as sinistrally coiled, although the figures depict dextral species.

If the standard source still doesn't completely convince, then seek an author with special expertise. I therefore consulted my copy of one of the great works in late-seventeenth-century paleontology, *De Corporibus Marinis Lapidescentibus* (On Petrified Marine Bodies) by Augustino Scilla (my Latin edition dates from 1747, but Scilla first published his work in Italian in the 1690s). I decided on Scilla as a final test case because he was a painter by trade a leading figure on the *seicento* in Sicily and he engraved his own plates. All hi snails are dextral species, and all are engraved with sinistral coiling. Clearly, i standard sources and noted artists all drew snails in mirror image from their natura occurrence, they must have been following a well-accepted convention of th time, not making an error.

But why would earlier centuries hav adopted a convention so foreign to ou own practices? Why would these older illustrators have chosen to depict specimen in mirror image when they surely knew the natural appearance of these shells? Di they devise this convention in order t make life easier for a profession founde on the principle that one carves in revers in order to print in the desired orientation


A dextral snail, shown with sinistral coiling in Musaeum Metallicum, *by sixteenth-century Italian naturalist Ulisse Aldrovandi*
AMNH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But if so, what aid could be provided by the convention of printing snails in reverse? I suppose that an engraver could then paste a picture directly on his plate and cut through with maximal visibility (whereas the usual technique forced him to invert the drawing before affixing it to the plate, thus making him view the sketch through the backside of the paper; but papers of adequate transparency must have been available, and I wonder if the usual technique really imposed any great hardship. Or did engravers mechanically copy an original figure in reverse orientation and then paste this copy onto the plate? If so, a convention permitting reversed printing would allow engravers to omit a time-consuming step).

Whatever the reason, the very existence of the convention does, I think, teach us something important: the conceptual world of pre-eighteenth-century zoology must have accorded little importance to the orientation of a shell. These men were not stupid, and they were not primitive. If they were willing to sacrifice what we would call "accuracy" for some gain in ease of production (or for some other reason not now apparent to us), then they must have held a notion of accuracy quite different from ours. The recovery of "fossil" thought patterns from such intriguing hints as this small, but previously unnoted, change in a practice of illustration provides the kind of intellectual lift that keeps scholars going.

The greatest impediment to such recovery—one that infested my own first thoughts on this issue and precluded any movement toward a proper solution after I had made my initial and accurate observations—lies in lamentable habits imposed by the twinned biases of progress and objectivity. We assume that we now do things better than at any time in the past, and that our improvements record increasing objectivity in shedding old prejudices and learning to view the world more accurately. We therefore interpret our predecessors, especially when their views differ from ours, as weighted down by biases and lacking in data—in short, as pretty darned incompetent compared with us. We therefore do not take them seriously, and we view their differences from us as crudity and error. Thus, we cannot understand the interesting reasons for historical changes in practice, and we cannot recover the older systems, coherent in their own terms (and often based on a fascinatingly different philosophy of nature), that made the earlier procedures so reasonable.

The key, in this case, lies in realizing that an apparent error in past practice represents a convention, now foreign to our concepts but evidently pursued for conscious reasons by our predecessors. We must still overcome one obstacle in striving to view the past more sympathetically (thereby gaining insight into present styles of thinking). We might understand that printing snails in reverse represented a convention, not an error, but still hold (via the bias of progress) that the history of changing conventions must record a pathway to greater accuracy in representation. We might, for example, hold (in utmost naiveté) that our predecessors once drew what they wanted to see, whereas we now photograph what actually is.

Two arguments should convince us that history marks no path from stilted convention to raw accuracy. First, I have talked with many professional photographers, and all recognize as a canard the old claim that their technology gave us objective precision, where only subjective drawing reigned before. Technological improvements in photography do make older styles of prevarication less possible. (In my book *The Mismeasure of Man,* I showed how one pioneer eugenicist doctored his pictures of supposedly retarded people to make them look more benighted. His retouchings are so crude that no one today, with a lifetime of experience in looking at good photographs, would be fooled. But he got away with his ruse in 1912, for few people then had enough experience to recognize a doctored photo, and retouching represented an accepted art for repairing crude shots in any case.) But other technological improvements make all manner of fooling around with photos ever more possible and elaborate (just think of Woody Allen as Zelig, or Tom Hanks as Forrest Gump, artificially incorporated into the great events of twentieth-century history by trick photography). Who can balance the gains and losses? Why speak of these changes as gains and losses at all? We have not dispensed with conventions for accuracy; we have only adopted different conventions.

Second—and the clinching argument that made me decide to write this essay—we have not, even today, abandoned all conventions for reversed illustration. In fact, one highly prestigious and technologically "cutting edge" field continues to present upside-down photographs, just as our forebears drew their snails right to left. How many readers realize that conventional photos of moons and planets are upside-down? (If you doubt my claim, compare the full moon on a clear night with the photograph in your old astronomy text). Modern astronomers, of course, are no more fools than the old snail illustrators. They present photographs upside down to match what one sees in conventional refracting telescope. (Or, rather, they print the photos as they are taken through such telescopes. Is this convention any different from carving a snail as one sees it onto an engraving plate and then producing the paper image in reverse?)

Clearly, astronomers feel that the trouble taken to print photographs from refracting telescopes upside down (thus rendering the object as it exists in the sky) would not be worth the gain. In fact, one might argue that reversing the photo would sow confusion rather than provide benefit, for with the exception of our moon, we cannot see features of other moons and planets with our naked eye, and therefore know these bodies primarily as seen through refracting telescopes—that is, upside down. I must suppose that the old snail illustrators also regarded the direction of coil as unimportant for illustration—and I would like to know why. I would also like to know what triggered the change from an accepted convention to a no-no.

I shall not, either in this forum or anywhere, resolve the age-old riddle of epistemology: how can we "know" the "realities" of nature? I will, rather, simply end by restating a point well recognized by philosophers and self-critical scientists, but all too often disregarded at our peril. Science does progress toward more adequate understanding of the empirical world, but no pristine, objective reality lies "out there" for us to capture as our technologies improve and our concepts mature. The human mind is both an amazing instrument and a fierce impediment—and the mind must be interposed between observation and understanding. Thus, we will always "see" with the aid (or detriment) of conventions. All observation is a partnership between mind and nature, and all good partnerships require compromise. The mind, we trust, will be constrained by a genuine external reality; this reality, in turn, must be conveyed to the brain by our equally imperfect senses, all jury-rigged and cobbled together by that maddeningly complex process known as evolution.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

REDISCOVER AMERICA

Natural History's Top Seven Drives Around the U.S.

By Andrew Bill

Sangre de Christo Mountains, New Mexico

Mark Abraham
Preceding page: Redwood National Park, CA
Photo by James Blank, Bruce Coleman

Broadly speaking, there are two types of vacationer: "tourists," who just want to unpack, unlace, and unwind and "travelers," who yearn for the romance of the open road with all its natural grandeur and glorious unpredictability—and who agree that nothing is quite so fulfilling as the act of traveling itself. For this second group, we have mapped out a collection of great drives. All are loops, beginning and ending in major cities; all take about a week, and all squeeze a different concentrated flavor from the U.S. They are not designed to cover every detail—that would curtail your freedom and surprise—but only to pique your interest, hinting at the extraordinary pleasures waiting beside the road. Bon voyage!

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As scenery goes, I-40 is hard to beat. It leaves Albuquerque and heads north on the Turquoise Trail, threading its way through mesas, wooded peaks, and a series of old mining towns that have become thriving artists' communities. Waiting up ahead is Santa Fe, a fascinating mix of two historic forces—Spanish colonial and Pueblo Indian—that surface in the many churches and museums. And when the past releases you, there are galleries, jewelry workshops, and cultural performances to keep you busy for at least a couple of days.

Motoring north again toward Taos, the winding road passes a scattering of Pueblo Indian settlements, built out of the earth in sculptural and pastel-toned simplicity, where Indian crafts and traditional performances welcome the passing visitor. Then comes Taos itself: its beautiful streets are lined with boutiques, yet remain faithful to its seventeenth-century origins. Nature takes center stage again as you leave the town and climb into the wilds of the Sangre de Christo Mountains, bridging gorges and crossing the 10,000-foot Bobcat Pass. The air is crisp, the sky a thin wedge of blue as you head down again through Cimarron Canyon, recalling such American myths as the Earp bothers and Jesse James.

Traveling east toward Springer, the road drops down to the prairies, putting another piece of the historic jigsaw into place. Fort Union, near Waltrous, was built only 150 years ago to deal with the "troublesome" Indians. Pecos National Monument reveals a more peaceful solution, the ruins of two missions built by Spanish Franciscans. Then it's back through Alameda to Albuquerque.

photo by Mark Nohl

A woman of Taos Pueblo bakes bread in a traditional earthen oven.

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Phil Degginger, Bruce Coleman

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As you head down the side of the Connecticut River, stop at Cornish for a visit to the house of the sculptor Augustus Saint-Gaudens (1848 to 1907) with its delightful garden and concert schedule (mid-June to mid-August). Then it's back again into nature, dipping and climbing south on 100, west on 9, and north again on 7 and 30 through the splendor of the Green Mountains until you reach Rutland and the Norman Rockwell museum containing 2,000 paintings.

Crossing Lake Champlain at Burlington, you enter New York State and a different slice of history—Fort Ticonderoga, built by the French in 1755, now restored and housing a fine museum of memorabilia. A fast drive east on I-90 brings you to Sturbridge, an entire town re-creating life in the 1800s. Then it's down on 95 to Rhode Island's capital, Providence, where the "mile of history" around Benefit Street recalls the days when George Washington slept here (really). A different golden era is on show in Newport, where the social crème de la crème of the nineteenth-century social set built their vainglorious "summer cottages" (in reality vast mansions) side by side on Bellevue Avenue. If you have time for a bit of beach, fine. If not, Boston awaits your return just to the north.

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way to hike around Sinks Canyon (where a river sinks into the earth), and the ghost town of South Pass City, grandly named in the throes of gold fever.

On Day Six, travel south from Rock Springs on Highway 191 to Flaming Gorge Recreational Area, then on to Vernal, the gateway to Dinosaur National Monument, to see paleontologists at work exhuming fossilized bones from the Jurassic era.

Finally take I-80 west to Fort Bridger, which dates back to the fur-trapping days, and continue on to Salt Lake City.

Mark Abraham

Mammoth Hot Springs, Wyoming

JUST DESERTS

Phoenix ••• Grand Canyon ••• Petrified Forest •••Tucson ••• Phoenix

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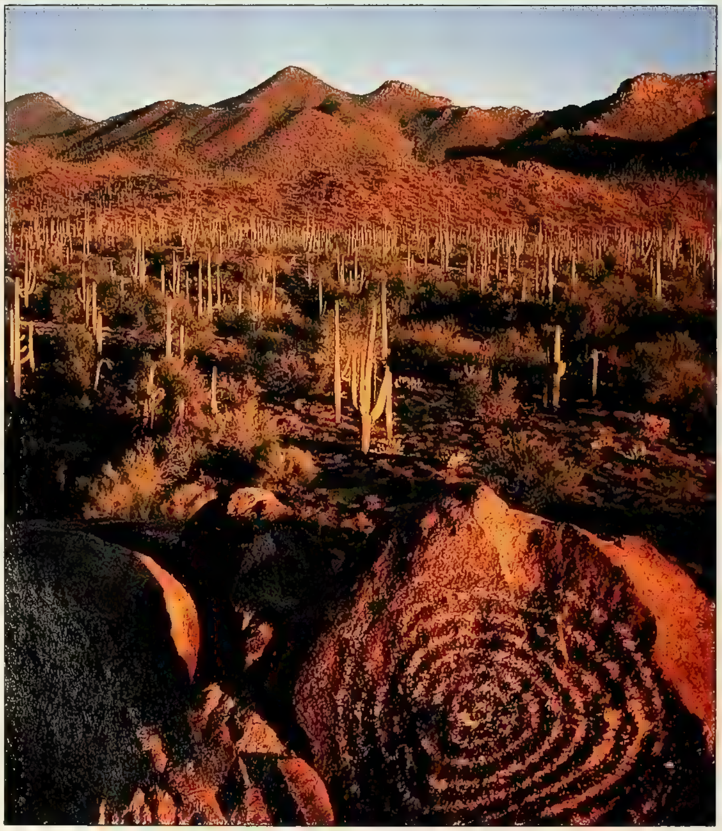
Plan to spend your first day in Phoenix, strolling through a museum or two. For flora the best spot is the Desert Botanical Garden; for southwestern Native American cultures, visit the Heard Museum. The next day, pick up the car and head north on I-17 to Montezuma Castle, the twelfth-century ruin of a five-story cliff dwelling. Then it's off again, through the mountains to Flagstaff, ideally reaching Sunset Crater Volcano National Monument an hour and a half before sunset. Put on hiking boots and find a lookout for the sunset and watch the volcano's ruddy soil change color with every passing minute. The next day, cross over into Navajo territory for what is perhaps the greatest natural sight on earth—the Grand Canyon.

Incredibly the natural wonders continue. Retrace Route 64 back to 89, then branch off right toward Monument Valley and the Navajo Tribal Park, stopping to see how the locals live and to wonder at the vast sandstone columns that look as though they have been planted in the desert floor. Continue south to the Petrified Forest and drive the 28-mile scenic road that meanders past logs that have literally turned to stone. The Rainbow Forest Museum explains the phenomenon.

Driving through the town of Globe through desert and woods on U.S. 60 you will come to the scenic Queen Creek Canyon and the Boyce Thompson Arboretum. The route then leads down into Tucson. Stop at the Saguaro National Monument and the Casa Grande ruins before returning to Phoenix.


Fred Hirschmann, Tony Stone

Saguaro National Monument, Arizona

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THE APPALACHIAN LOOP

Washington D.C. ••• Asheville ••• Lexington
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Connecting many of the most scenic spots in Virginia and North Carolina, this 1,200-mile route takes in the raw beauty of the Skyline Drive and other escarpment drives, historic towns like Asheville, and silvery rivers hemmed in by gorges. Hikes, canoe-descents and specialized museums complement the beauty of the open road.

Where better to start than Washington D.C. itself, home to some of the world's finest museums. After the city's urban attractions it's time to head for the opposite extreme along I-66 west toward Front Royal and the Skyline Drive, one of the most spectacular scenic highways in the country. Take in the beauty of the Shenandoah National Park before leaving the Blue Ridge Parkway at Waynesboro. At nearby Staunton, pick up I-81 and take it south before turning at Max Meadows to rejoin the Parkway at Fancy Gap.

Traveling south for 190 miles (now through North Carolina), you wind up steep grades, passing scenic overlooks, small museums, and Linville Falls before arriving at the popular mountain resort of Asheville. Two must-sees are the Biltmore Estate, a 250-room chateau that was once home to the Vanderbilts, and

Tim Davis, Tony Stone

Great Smoky Mountains

Those interested in a leisurely add-on to the scenic loop should consider North Carolina's Crystal Coast, stretching along the Southern Outer Banks from Cedar Island to Cape Carteret. The Coast is best known for its charter fishing, seafood restaurants and the historic town of Beaufort. Just 45 minutes away up the Neuse River is the town of New Bern, home to the historic Tryon Palace. A guided tour of this residence of royal governors prior to 1770 (when North Carolina became a state) carries the visitor back through the centuries. The meticulous reconstruction covers 19 rooms including the council chamber, presided over by a portrait of King George III himself, the book-lined library, and two other buildings from different periods.

Chimney Rock to the southeast. Leaving the Parkway at Asheville along I-40, your route will curl up through the Great Smoky Mountains to Jefferson City and I-81. Take I-77 north at Wytheville through Jefferson National Forest to the New River Gorge National Park. If a rafting trip has ever crossed your mind, this is the place to indulge yourself. Sign up with one of the better outfits such as Class VI based in Lansing.

Refreshed and ready, it's back in the car for the drive through heavily wooded mountains from White Sulphur Springs to Lexington, home to several historic museums, and back again to I-81. This road will take you north to Winchester. From there it's an easy 60-mile hop back to the capital.

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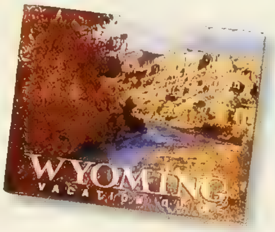

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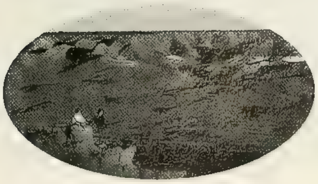

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San Antonio ••• Big Bend National Park
Guadelupe Mountains ••• San Antonio

David Muench, Tony Stone

Big Bend National Park, Texas

This 1,250-mile loop around the western region of Texas scratches away at the surface of the state to reveal the soul within. It climbs to high peaks and drops down through the desert ecosystems to the bed of the Rio Grande. It cuts through the strata of border history and links up the main points of scenic and recreational interest.

On your first day, spend a few hours getting to know San Antonio, home to a lot more than the Alamo, the fortress that Crockett and Bowie defended against Santa Anna almost (but not quite) as they did in the movies. The next morning, pick up the route (I-35 south to U.S. 57) via Batesville LaPryor to Eagle Pass. Then go on to Del Rio (U.S. 90) via Normandy and Quemado to take in the Rough Canyon Recreational Area. West of Comstock is the Seminole Canyon Historic State Park.

Continue west on U.S. 90 via Langtry to Marathon, then strike south on 385 to the famous Big Bend National Park, nestled in the bottom of Texas along a bend in the Rio Grande. The Park offers many activities, such as hiking the three-mile trail to Lost Mine Peak, horseback riding, or even rafting the river itself. And when you have had your fill, follow the border west from Lajitas along the Scenic Byway that climbs sharply over passes, plunges into valleys and passes Fort Leaton State Park, a restored Spanish fortress. At Presidio, take U.S. 67 north to Marfa and Fort Davis, with its restored frontier outpost. The road then curls up through rangeland and mountains before reaching I-10. Head west, then pick up SR 54, a quiet and incredibly beautiful road that runs along the Sierra Diablo Wildlife Management Area and into the Guadalupe Mountains National Park. Angle down through Pecos back to I-10. From here it's just a straight 322-mile road back to San Antonio.

SOUTHERN SPICE

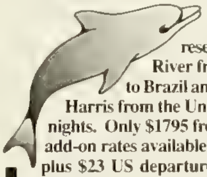
New Orleans ••• Montgomery ••• Jackson ••• New Orleans

Here is a drive saturated with the flavor of the Old South. It leads past Civil War sites, charming antebellum homes, and towns bright with azalea and rhododendron. It weaves through cotton fields, woodlands, and along the banks of the languid Mississippi.

Before picking up the car, take a day to explore New Orleans on foot. Aim for the Garden District, checkered by elegant homes and laced with cobblestone sidewalks. After a gumbo lunch, stroll the picturesque streets of the French Quarter, soaking up the atmosphere in St. Antony's Garden and, finally, in a Bourbon Street jazz bar. The next morning, set off east along the coast road to Dauphin Island, an Audubon bird sanctuary. On the way back toward I-10, drop in to tour Bellingrath, an old brick house (now a museum) with its 65 acres of gardens, a riot of camellias, azaleas, and roses. Move on up to Montgomery, stopping in Old Alabama Town where Shakespeare's plays are performed at the State Theater from November to August. The next major stop is Tuscaloosa, the home of the University of Alabama with its Museum of Natural History and the Mildred Warner House with its impressive collection of American art.

Looping west from Columbus, the road joins the Natchez Trace Parkway, once an old pioneering trail. Tracing its history you come chronologically and literally to the Vicksburg National Military Park where a 16-mile drive explains the famous siege of 1863 in which 17,000 Confederate and Union soldiers were killed. From there, it's south to Natchez on the languid Mississippi to wallow in the slow-paced atmosphere of the Old South.

In Natchez itself many of the antebellum homes only open their doors from March 7 to April 5 and from October 6 to 26. But there are plenty of restored plantation houses in the area, including Rosedown (filled with Empire and Federal furnishings), near St. Francisville, and Nottoway (at White Castle), with its evocative all-white ballroom. From this mansion, it's a gentle drive along the banks of the river back to New Orleans.



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NH03

Caterpillars Roll Their Own

Folding and bending leaves hundreds of times their size, moth and butterfly larvae build shelters in the trees before they graze on the greenery

by Terrence D. Fitzgerald

Destined to become a tiny, iridescent moth, the cherry leaf roller begins its life as a flat, legless leaf miner in a black cherry tree. Feeding on sap that oozes from the plant cells it slices open with scissorslike mandibles, the insect tunnels within the leaf for a week or so and then metamorphoses into a caterpillar possessed of legs and a spinneret. Somewhere within the complex of neurons that instruct this caterpillar's behavior, a program switches on, directing and monitoring a building process. The creature chews its way out of the leaf and moves actively about on the surface, appearing to assess the leaf's features salient to the task that lies ahead—constructing a shelter by tying the leaf together with silk.

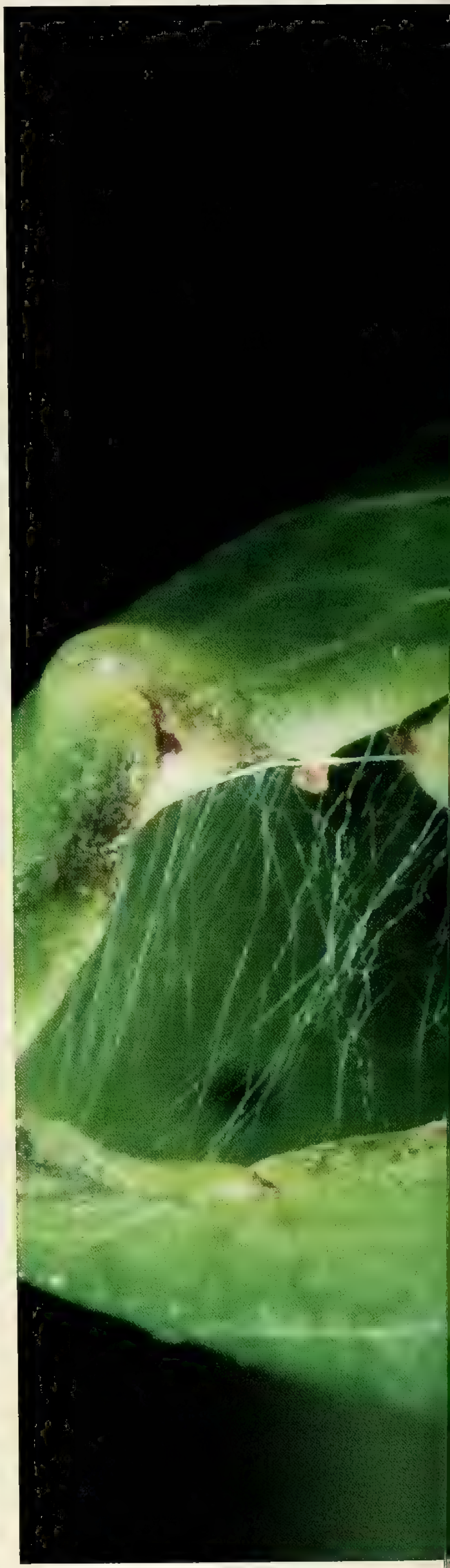
In late spring and early summer, in virtually every corner of the world, caterpillars are busily at work rolling, folding, and tying the leaves of trees and plants. In the northeastern United States, leaf-shelter-building caterpillars are particularly abundant on cherry, maple, oak, and poplar trees; but one species or another may be found on almost any kind of plant. Although the caterpillars are often small, cryptically colored, and short-lived, the compact shelters they create are almost always conspicuous and endure long after the occupant has departed. In some years, shelter builders may be remarkably abundant. I have seen large cherry trees in which every new leaf the tree produced was quickly taken over by a leaf roller.

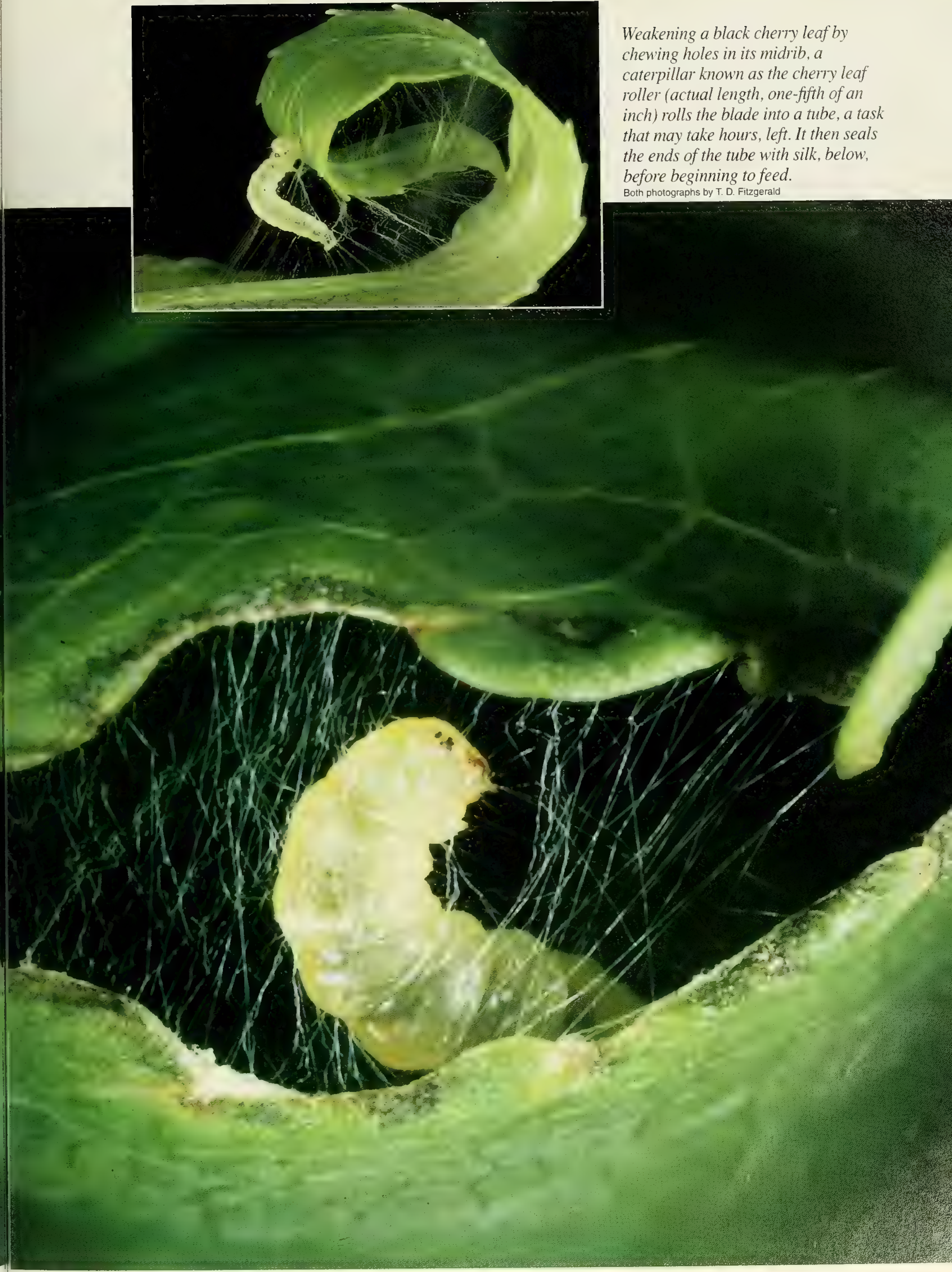
Leaf shelters protect residents from predators, but they serve other purposes as well. On sunny days, the shelters act as miniature greenhouses, trapping air that is moister and warmer than the outside atmosphere, and thereby creating a microclimate conducive to the rapid growth and development of the resident caterpillar. Some species construct shelters with vertical, open-ended leaf rolls that function as chimneys. These tubelike structures set up convection currents that draw fresh air through the shelters, preventing them from overheating on hot, sunny days. Leaf shelters also enable some caterpillars to feed on plants that would normally be poisonous to them. The leaves of St. John's-wort, for example, contain hypericin, a toxin that is activated by sunlight. Leaf rollers that feed on this plant can do so only because the walls of their shelters filter out the sun's catalytic rays.

Although we knew something about the form and function of leaf shelters, we knew comparatively little about the shelter-building process. How, for example, are the caterpillars able to generate the forces needed to fashion these structures? This question attracted my attention and that of my colleague Karen Clark soon after we began to study the behavioral ecology of these creatures. Impressed by the skill and apparent ease with which shelter builders manipulated leaves many times their size and mass, we reviewed the scientific literature and found that the forces generated during the shelter-building process had not been previously measured. Moreover, no one had determined exactly how the requisite forces were produced. Although we knew that the caterpillars needed to produce forces of substantial magnitude, we were both surprised and delighted when our studies eventually showed that for their size, leaf-shelter-building caterpillars generate forces greatly exceeding those previously reported for any insect.

A newly transformed cherry leaf roller caterpillar measures barely one-fifth of an inch and weighs under one ten-thousandth of an ounce. By comparison, the leaf it manipulates is a huge structure that can easily weigh 150 times as much. To put this in perspective, the task of the caterpillar in converting its leaf into a shelter is roughly equivalent to that confronting a six-foot-tall, 150-pound human charged with manipulating a 100-foot-long object that weighs nearly eleven tons. What is most remarkable is that the caterpillar manipulates the leaf entirely with strands of silk so fine (each approximately one-fiftieth the diameter of a human hair) that they are virtually invisible to the unaided human eye.

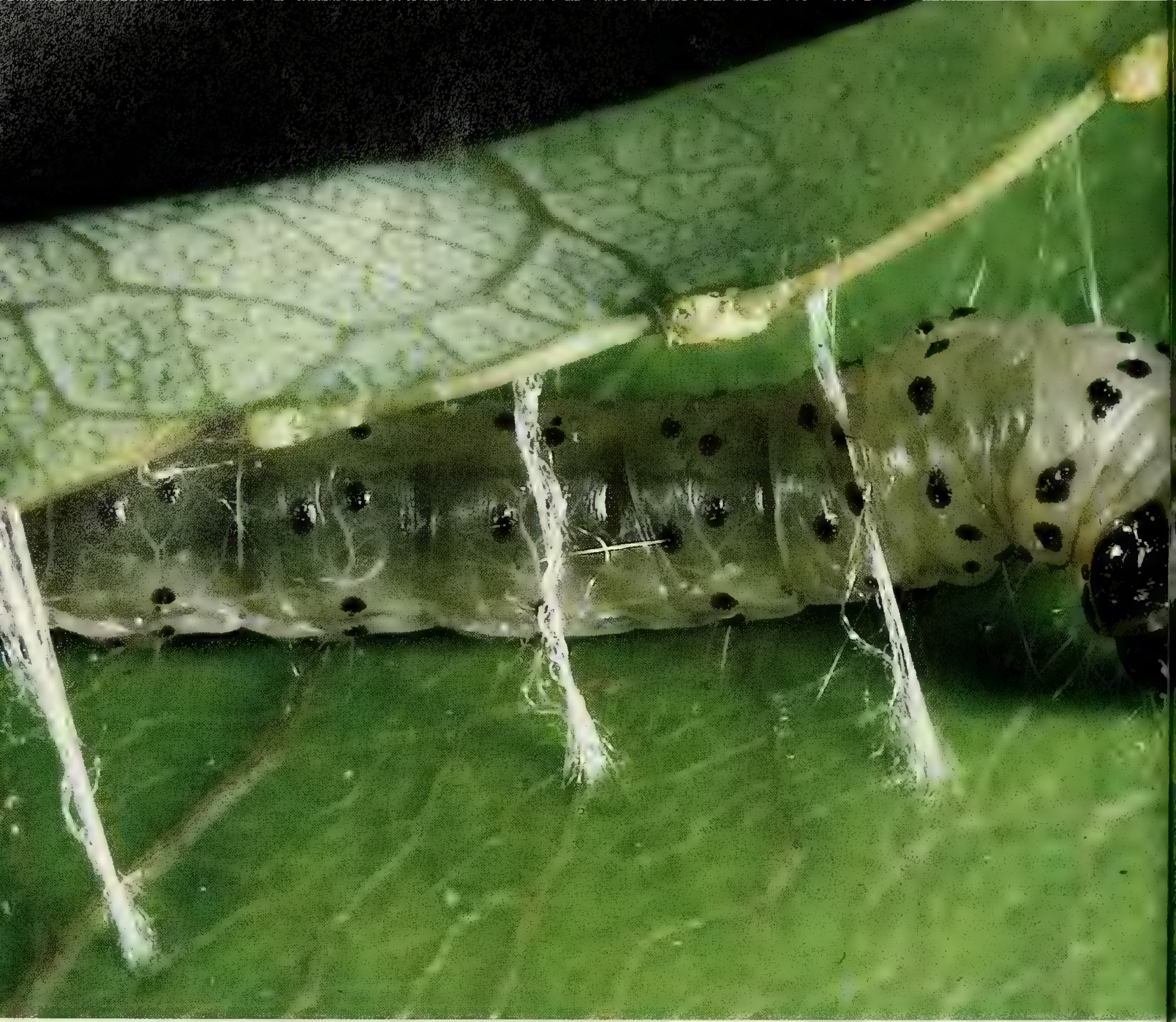
When we began the study, we took a broad approach, making general observa-





Weakening a black cherry leaf by chewing holes in its midrib, a caterpillar known as the cherry leaf roller (actual length, one-fifth of an inch) rolls the blade into a tube, a task that may take hours, left. It then seals the ends of the tube with silk, below, before beginning to feed.

Both photographs by T. D. Fitzgerald



tions of some twenty or so species we found in trees near our college campus in upstate New York. The cherry leaf roller, *Caloptilia serotinella,* particularly impressed us with the apparent ease with which it accomplished the seemingly Herculean task of converting leaves into tightly sealed shelters.

If the cherry leaf roller finds its natal leaf acceptable, it stations itself near the tip and begins to roll the leaf into a tube. When it has completed the rolling phase of construction, which may take hours, the caterpillar closes the ends of the tube and feeds sequestered within the sealed structure. But more than this is involved. In a marvelous display of evolutionary wisdom, the caterpillar stops periodically during the rolling process to chew holes in the rigid midrib that runs the length of the leaf. This rib is a major source of resistance to rolling, a fact that the brain of the caterpillar has assimilated over the long haul of time. The dozens of wounds the caterpillar inflicts in the midrib weaken the structure substantially, making the job of rolling that much easier.

Exactly how is the cherry leaf roller able to manipulate its leaf? Some early investigators reported that shelter-building caterpillars somehow physically pulled the surfaces of a leaf together, then bound them in place with silk. Our observations led us to reject this theory. Others suggested that the silk dries after it is spun and shrinks in the process, pulling together the surfaces to which it is attached. While this scenario seemed plausible, we soon learned that newly spun caterpillar silk showed no tendency to shrink, no matter how long it was allowed to "dry." Quite the contrary—and to our initial surprise—we found that wetting causes the silk of shelter-building caterpillars to swell in diameter but to contract almost instantly to less than half the original length. This phenomenon, known as supercontraction, was first reported to be a property of some spider silks.

When we discovered that caterpillar silk also supercontracted, it occurred to us that leaf-shelter builders might be harnessing the energy of supercontraction by wetting their silk after it was spun. But after many hours of observation, we concluded that this was not the case. Moreover, when we measured the forces generated by the supercontraction of wetted silk, we found them to be inadequate to the task of manipulating a leaf. If neither drying nor wetting of silk nor direct manipulation of the leaf was involved, how were caterpillars generating the forces needed to build their leaf shelters? The answer, we eventually discovered, is that the caterpillars impart minute amounts of potential energy to

T. D. Fitzgerald

With columns fashioned from hundreds of silk strands, a poplar leaf roller, left, shapes a feeding shelter. As larvae, many moth and butterfly species specialize in rolling, tying, or folding the leaves of a single tree or plant species. The rolled oak leaves on the branch below reveal the presence of the green oak roller, the caterpillar of a European moth.

Stephen Dalton; NHPA

their strands by stretching them as they are spun out.

Caterpillars synthesize and store silk proteins in a pair of elongated abdominal glands. When needed, the proteinaceous liquid mixture passes through the spinneret. Some of the silk proteins align to form a fiber; others form a sticky coating over the fiber. The liquid silk is not pushed through the orifice of the spinneret, like dough through a cookie press, but is pulled from the spinneret as needed.

To fix a strand of silk between two points on a leaf, the larva starts by touching its spinneret to the leaf, tacking down the sticky surface of its silk. It then lifts its body and swings rapidly away from the attachment point, pulling a long, continuous strand from the spinneret. As it is drawn through the spinneret, the liquid silk gels irreversibly, loses water, and emerges as a dry strand. What is most important for the purpose of manipulating leaves, however, is that the newly formed strand is elastic. This enables the caterpillar to transfer energy to it by stretching it before it is tacked down again. If a newly fastened strand is cut in the middle, it snaps away from the cut as a stretched rubber band would. Thus each strand a caterpillar spins exerts a minuscule contractile force along its axis. The cumulative contractions of the many strands spun during the shelter-building process enable the caterpillars to manipulate leaves.

Just how much force can a caterpillar generate by stretching silk? To determine this, we arranged for caterpillars to spin strands of silk between two points on a leaf, one of which was fastened to an immovable surface and the other to a weight situated on the pan of a highly sensitive electronic balance. Contraction of the strands spun between the leaf sections in this simple tensiometer acted to displace the weight upward, allowing us to quantify the forces involved.

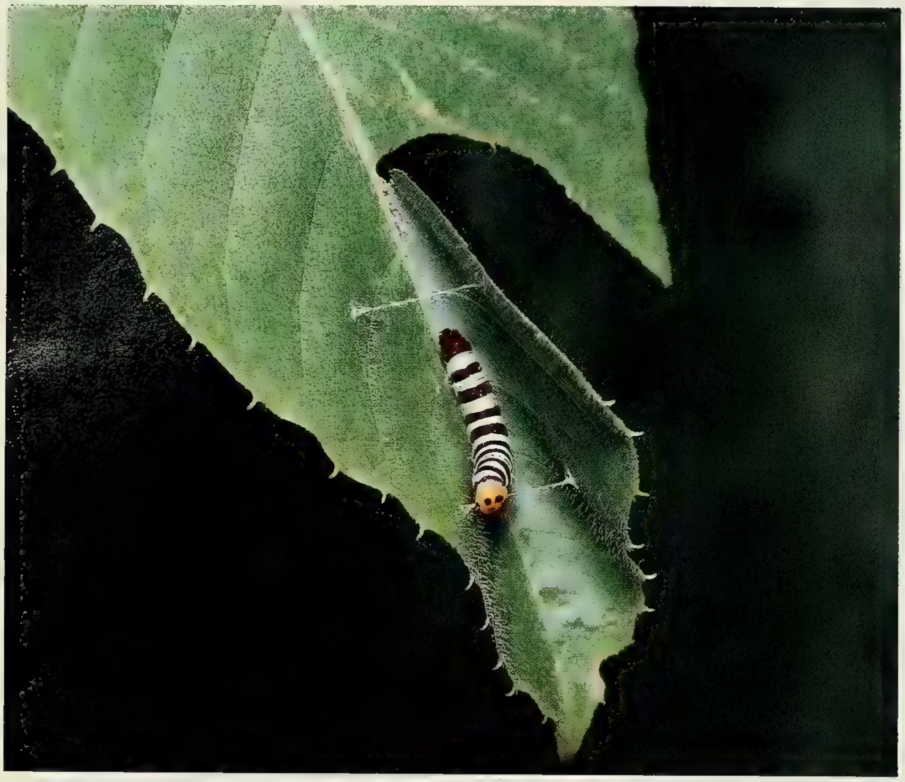
When spinning in our tensiometer, cherry leaf rollers adopted the fast-paced, rhythmic spinning behavior characteristic of shelter builders. Stationed midway between the end points of their silk columns, the caterpillars swung their bodies in a nonstop cadence from one leaf surface to the other, bridging the gap with strand after strand of silk. By recording the activity of the spinning caterpillars with a video camera fitted with a microscope lens, we determined that they required only four-tenths of a second to draw a strand from their spinnerets and two-tenths of a second to glue it down. During nonstop spinning blitzes, lasting an average of seven minutes, the caterpillars laid down strands at the rate of about 100 per minute, and expended nearly three feet of silk.

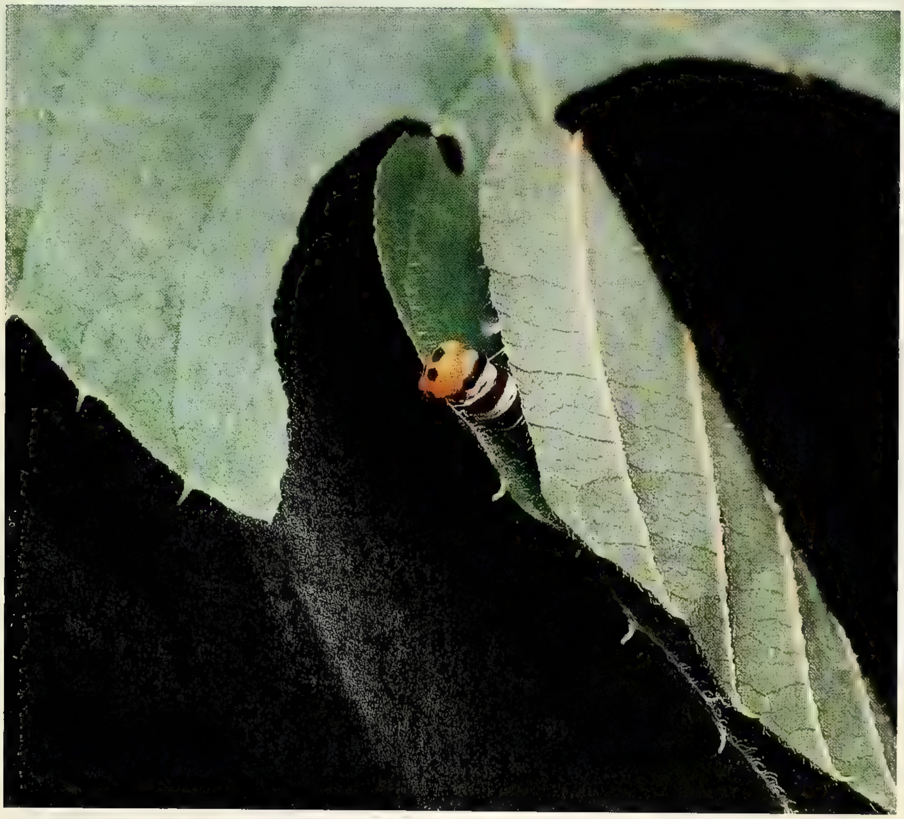
Calculations based on caterpillars spinning in our tensiometer showed that, on average, each strand exerted a one ten-thousandth-ounce force on the leaf. While this caused an unrestrained leaf to move a mere three ten-thousandths of an inch, the hundreds of strands laid down during a spinning bout advanced the leaf into the roll about one-fifth of an inch. The caterpillars alternated bouts of spinning with periods of rest, feeding, midrib weakening, and apparent inspection, completing their shelters in four to ten hours.

Although leaves ordinarily yield under the force of stretched silk—so that only a dozen or so of the hundreds of strands spun during a spinning bout are simultaneously taut—leaves in our tensiometer re-

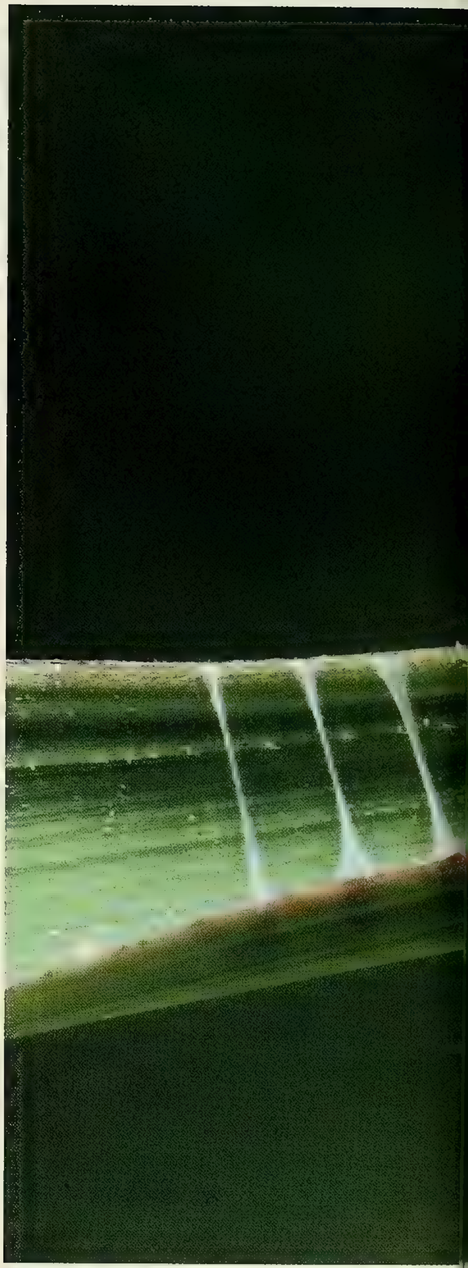
Shelter builders, such as the skipper caterpillars below and right, exude silk from a spinneret near the mouthparts. Sticky and elastic when it emerges, the silk is tacked to the leaf and pulled away from the attachment point. A caterpillar harnesses the contractile energy of a newly produced strand to manipulate a leaf that it could not otherwise move.

Photographs by Hiroshi Ogawa; Nature Production



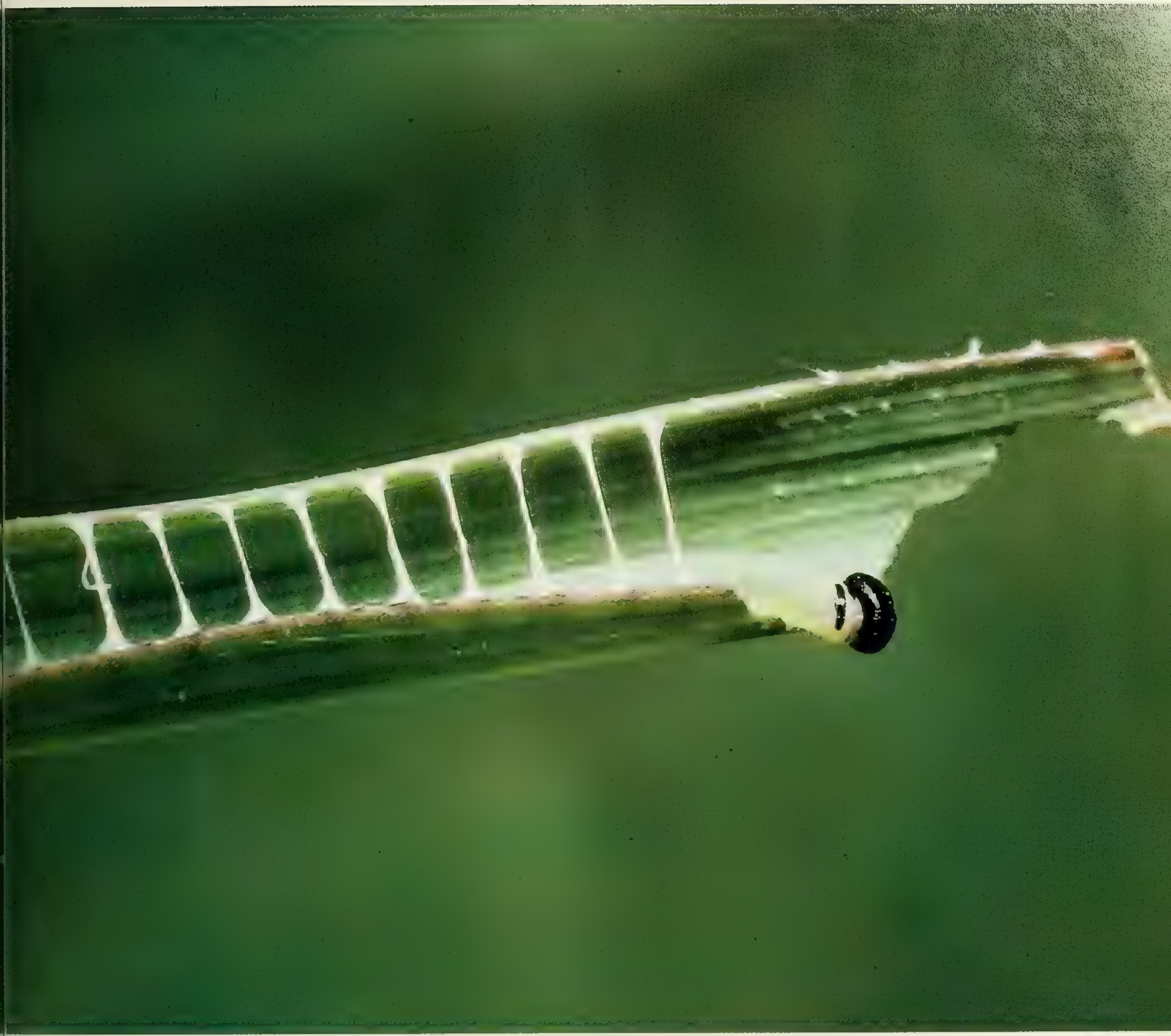


Satoshi Kuribayashi; Nature Production



sisted all efforts of the caterpillars to draw them together. This allowed us to determine just how great a force the cherry leaf roller was capable of generating. Caterpillars created columns of silk having thousands of strands, all simultaneously taut. By pulling in unison, the strands enabled individual caterpillars to generate as much as a four-tenths-ounce force—huge for so small a caterpillar and many times that needed to roll even the most stubborn of leaves. This force is approximately 4,000 times greater than that which would be exerted were the caterpillar to displace the leaf by a force equal to its own weight. On a human scale this would be the equivalent of a person of average weight exerting a 300-ton force!

It is not, however, entirely fair to upscale from caterpillars to humans. The rel-



ative strength of a large animal is much less than that of a small animal. This is true because the strength of an animal is proportional to the cross-sectional area of its muscles, while its mass increases at a rate proportional to its volume. Thus, as animals grow, their mass increases much faster than their strength. A caterpillar with the mass of a human would lack the strength needed to energize each of a succession of thousands of giant silk fibers—were they to exist—with the potential energy needed to produce such a relatively large, total contractile force. Smallness empowers caterpillars.

The forces that we measured for the cherry leaf roller are by no means the largest that leaf-shelter builders generate. Most shelter builders live solitary lives, but some, such as the ugly nest caterpillar, *Archips cerasivoranus,* live in colonies containing up to several hundred individuals. The caterpillars colonize small chokecherry trees and form the nucleus of their nest by tying together a few leaves. As their demand for food grows, the caterpillars poke their bodies out of the existing nest to attach stretched strands of silk to nearby leaves, which are slowly drawn in. The efforts of many individuals spinning together allow *Archips* caterpillars to generate forces that greatly exceed those of solitary shelter builders. By concerted effort, the caterpillars can draw entire branches together, and by the time they have finished building their nest, the entire top of a sapling may be tightly bound.

How do the forces that leaf-shelter-building caterpillars generate compare with those measured for other insects? We already know that insects can lift heavy loads for their size and jump very long distances. An ant, for example, can transport a pebble more than fifty times its weight. A honeybee can pull a load that exceeds its weight by a factor of twenty, and a flea can broad jump about 200 times its length. In one study, a beetle wearing a specially designed harness was able to lift 850 times its own weight! The feats of all these insects depend on a single, massive force generated directly by muscle contractions. The larvae of leaf-shelter-building caterpillars would find themselves no match for any of these insects in a contest that depended on brute strength. But by storing a small amount of energy in each of a large number of silk strands, even the smallest shelter-building caterpillar can exert a cumulative force that—on a per unit, body

William E. Ferguson

A row of feeding shelters, right, built by caterpillars of an unidentified species, border a leaf in Malaysia's Gombak Valley. Leaf-rolling caterpillars, virtually worldwide in distribution, also create shelters by tying leaves together and by binding whole branches of foliage into tents. Below: A silver-spotted skipper, native to the American Northeast, has bound together the leaflets of a black locust, its food plant.

Norm Thomas; Photo Researchers

mass basis—greatly exceeds that which any of these insects is able to generate through sheer muscle power alone.

Although our studies show that leaf-shelter-building caterpillars manipulate leaves by harnessing the forces generated by the axial retraction of stretched silk, the extreme shortening of silk that occurs when it is wetted also appears to contribute to shelter building, but in a more indirect fashion. During the leaf-rolling process, the tension on load-bearing strands is gradually relieved as new strands are added and the older strands eventually slacken. As the strands are drawn into the damp interior of the roll, they absorb water and shrink instantly to a fraction of their original length. The supercontracted strands bind and secure the structure, making it virtually impossible for the leaf to come unrolled or to be pried apart by some small predator intent upon capturing the resident.

Interestingly, we found that when wetted, the silk of leaf-shelter builders shortened much more than that of species that used their silk for other purposes. The wetted silk of the cherry leaf roller, for example, contracts instantly to about one-third its initial length, whereas that of the *Euonymus* caterpillar—a species that does not manipulate leaves but spins a loose web of silk—shortens by only 10 percent. Thus, the extreme extent to which the silk of leaf-shelter builders shortens when wetted probably represents an adaptation to the shelter-building process.

Having invested many hours in observing the cherry leaf roller over the past four summers, I cannot help but view the animal as an evolutionary triumph. In this tiny package are the instructions for both mining and rolling a leaf, and the machinery and materials needed to carry them out. Although Karen Clark and I derived considerable satisfaction in addressing the question of how the caterpillar is able to manipulate a leaf many times its size and mass, we remain intrigued by the broader scope of the insect's behavior. How are instructions that are stored in the nervous system of the caterpillar translated to seemingly intelligent action? Does the caterpillar's nervous system render it a mindless automaton or does it provide the caterpillar with at least a glimmer of consciousness and awareness of task? Although—in its more general form—this question is as old as the study of animal behavior itself, it remains unanswerable and is among the most perplexing of all of nature's secrets. □

Photographs by Mitsuaki Iwago

Re

A male red kangaroo rests in the Australian outback.

angaroos, the Kings of Cool

Champions at dissipating heat in the desert, these marsupials have the jump on most large mammals

by Terry Dawson

A mob of red kangaroos hopping powerfully and gracefully across Australia's flat grasslands is an unforgettable sight. Although the kangaroos and their "outback" ecology have long intrigued biologists, the large marsupial's special adaptations to its severe, arid environment are just becoming known.

The red kangaroo, which inhabits dry plains throughout Australia, is a large species with marked differences between the sexes. Males are generally a rich, rusty brown. Females may be similarly colored but are often a smoky blue and are therefore called blue-fliers. Both sexes grow through most of their lives, and males reach 175 pounds, sometimes 200 pounds or more, in areas where restrictions on shooting allow them to reach full size. The much smaller females commonly weigh about 50 to 65 pounds, with a few individuals reaching more than 85 pounds.

Given the extremely harsh climate in which they live, kangaroos lead surprisingly long lives—as much as thirty years—and may still be breeding when in their twenties. The outback takes a heavy toll on youngsters, however; only after a sequence of rainy years has produced lush forage do many survive to join the adult population. In very dry years, virtually all young die before entering the pouch; even in moderate years, most do not survive much beyond weaning. Many desert mammals go through such boom or bust population cycles, in which the few survivors of a severe drought become the base of a rapidly recovering population.

Red kangaroos' adaptations for life in dry, open country are surprisingly recent. Fossil evidence suggests that they descended from ancestors allied to the euro, or inland wallaroo, within the past million years, while other kangaroo species have fossil histories dating back in the millions of years. But despite the species' late emergence, the special adaptations of red kangaroos to arid conditions have given them dominance in the outback.

When they have to move quickly, red kangaroos can sustain speeds of fifteen to twenty-five miles per hour for several

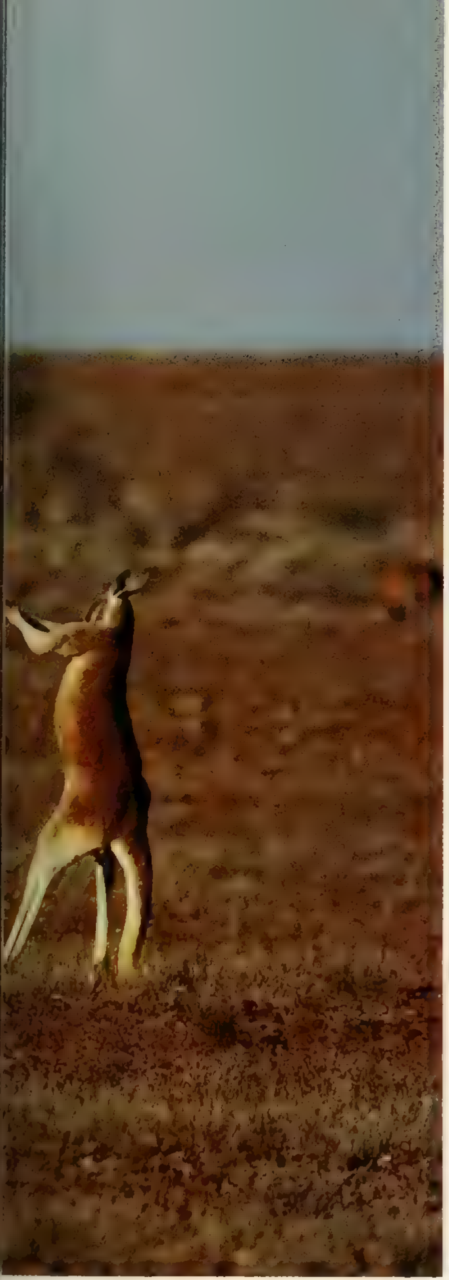
miles and may approach forty miles per hour for short bursts. For this reason, zoologists long believed that the key to the red kangaroo's survival was its capacity to cover large distances rapidly, enabling it to exploit widely scattered resources.

Research at the University of New South Wales, where my colleague David Croft and I work on red kangaroos, has helped to debunk that idea. We have established that although they can pour on the speed when necessary, red kangaroos are rather sedentary and territorial animals. If they survive adolescence, individuals establish small home ranges of about 2.7 square miles for females and 3.9 square miles for males. A male's home range may overlap those of several females. Once settled, individuals often use one or two favored resting sites (clumps of trees or bushes) for many years. Although they occasionally travel considerable distances to find better food during droughts, most red kangaroos eventually return to their home bases.

Such bases provide the animals with a measure of security in the vast, dry outback. A viable territory generally includes some productive grazing land, a stand of shade trees, and access to a reliable water source within ten miles or so. Kangaroos get to know their home ranges intimately and can find the best food and shelter whatever the season. Generally, they feed on grasses, plants, and shrubbery. Dingoes and humans are their main predators, although eagles and foxes occasionally take young ones. In dingo country, red kangaroos need to know where predators might lurk and what the feasible escape routes are. Familiarity with known resources far outweighs any advantages of a nomadic existence.

As grazers, red kangaroos need to extract adequate nutrition from sparse patches of dried-out grass. During dry years, they live almost entirely on such unpromising fare, which is largely made up of cellulose and lignin, structural carbohydrates that are not amenable to normal enzymatic digestion. Thus—like many other mammalian herbivores—kangaroos have evolved a specialized digestive system to process this fibrous material.

Microorganisms—specialized bacteria and some fungi and protozoans—live in the "fermentation vat" of the kangaroos' expanded foregut. (Ruminants, such as sheep and deer, have independently evolved similar systems.) In red kanga-



Left: Using his strong tail for support, a male red kangaroo (at right) stretches to his full height, attracting the attention of nearby adolescents and females. Below: Kangaroos visit a water hole. Although they can go two weeks without water, they will risk danger for an occasional drink, usually at night.

roos, this fermenting vegetation may make up about 10 percent of the animal's total body weight. Since there is virtually no oxygen in the chamber, the microorganisms use only a small amount of the plants' energy; the excreted remainder, nutritious, small fatty acids, can then be reabsorbed and metabolized by kangaroos.

From dry, poor feed, the microoganisms can also make all necessary vitamins and convert diverse nitrogen compounds into usable proteins; they also break down the toxic substances found in common desert plants. In emergencies, the large, fluid-filled chamber may also act as a water reserve to keep the kangaroo from drying out.

A low resting metabolic rate is a general characteristic of marsupials; fast as they may be, red kangaroos spend most of the day resting. Oddly, slow movement is energetically more costly to them than hopping. When "walking," red kangaroos use their thick tails as an "extra leg," which takes a good deal of energy. However, once they start hopping, energy costs stabilize, at least initially. And at their normal progression of fifteen to twenty-five miles per hour, they use less energy than do most running animals. Although direct evidence is not yet available, we think they become even more efficient at the much higher speeds of which they are capable. Their upper limits seem to be about thirty-five to forty miles per hour, but speeds above that have been reported. While we don't yet understand how red kangaroos can achieve so much power and speed while spending so little energy, we suspect that they are using the principle of the spring, storing energy for each hop in the elastic recoil of the massive tendons and ligaments in their legs, tails, and backs.

Despite their ability to travel so efficiently, red kangaroos living in harsh country rarely set up home ranges more than ten or fifteen miles from water. They drink infrequently and presumably could go much farther to find water. But while hopping is an energy efficient way to travel, a thirty-mile round trip under dry conditions would still require at least a day's worth of intensive foraging. To conserve precious energy, nearby water is essential. Conserving water also cuts down the risk of encountering predators that may lie in wait at unfamiliar water holes.

Red kangaroos drink much less often and use less water than other large mammals in the Australian rangelands. In Australia's outback, they frequently inhabit some of the same areas where sheep graze. With their special adaptations to these dry plains, the kangaroos have a major advantage over livestock: they need much less water and food. Their lower metabolic rate and more economical form of locomotion requires less energy, and they usually do not compete with sheep for resources.

Sheep drink twice a day during summer, but we found that red kangaroos generally drink about once a week. In a comparative study we did one summer, my group fitted numbered collars on fifty red kangaroos. We caught them by using a one-way gate on a fenced-in water hole, then observed which ones returned during the next two weeks. None returned to drink in less than three days, and a third of the animals went for more than two weeks

Although this joey seems too large to reenter its mother's pouch, it can still manage to get inside. Youngsters do not permanently vacate the pouch until they are about eight months old, and they continue to suckle for four more months. Most, however, do not survive for long after weaning.

between visits to the water hole. Another finding was that red kangaroos used only a quarter of the water used by sheep. Red kangaroos specialize in selecting greener, moister vegetation, which can provide much of their water needs. Unless there is a severe drought, during the cooler two-thirds of the year they can meet their water needs solely from feed.

Among the red kangaroo's many physiological adaptations to its habitat is the ability to excrete salts concentrated in urine, thereby losing little water. Urea, the waste product of protein metabolism, is absorbed from the urine and passed back to the foregut. This process not only allows the urea to be recycled into usable protein but also results in further conservation of water. Relatively dry feces are also produced via an elongated large intestine and rectum.

When conditions are relatively cool and dry, much of the animal's water can be retained. In hot weather, however, some water must be used for cooling. Red kangaroos can lose heat economically through panting, sweating, and licking. Among mammals, desert red kangaroos are champions when it comes to dissipating excess

A mob of kangaroos hops across an arid Australian plain; a large adult can cover thirty-three feet in a single jump.

A red kangaroo, below, peers from behind a shade tree. Most adults' home ranges include a clump of trees to provide relief from the midday sun. Opposite page: Using his short but dexterous upper limbs, a male kangaroo scratches and grooms himself with his sharp, pointed nails, leaving visible furrows across his red fur.

heat with a minimum of water loss.

Panting is the most common method used by resting red kangaroos to cool off. They can adjust their rate of evaporation by varying the air flow through their nostrils. Excess body heat is lost from a small area in the nose, so the heat-carrying blood has to flow at a much higher rate than usual. When conditions have gone from cool to hot, we have measured an increase in blood flow to a red kangaroo's nasal surfaces of sixty-six times normal.

Kangaroos also sweat, but only when exerting themselves. When moisture evaporates, the skin surface becomes cooler than the body core, and the blood transports heat outward to lightly furred surfaces (tail, legs, forearms, and shoulders) for dissipation. While this method is effective, cool skin attracts more heat, which requires more sweat.

Panting saves water because the dense, reflective fur that covers much of the kangaroo's body insulates it against heat coming in from outside. Prolonged hopping, however, raises the metabolism to more than twenty-five times the basal rate. Considerable heat is still lost from the respiratory tract as the animal pants heavily to get extra oxygen, but sweating then kicks in as an auxiliary system. A unique feature of kangaroos is that, unlike other mammals, they stop sweating the moment exercise ceases, even when their body temperature is still high. Switching off sweating to fall back on panting saves a lot of water.

In a third strategy to reduce heat, the animal will drop fluid from its mouth and nasal glands onto its forearms and spread the moisture by wiping and licking. In very hot weather, these glands work overtime. Until thirty years ago, kangaroos (and all marsupials) were thought to be inefficient in regulating their body temperatures by this method. Since the licked area was small, how could it play a significant role in heat loss for this fairly large animal? The problem was solved when we found a superficial network of fine blood vessels under the furred area of the forearm, precisely where the kangaroo spreads its fluids. When the kangaroo becomes too warm, marked increases in local blood flow just beneath these surfaces show that licking is indeed an important extra mechanism for losing heat.

The kangaroos' behavior also helps conserve water during the extremely hot summers. Air temperatures that reach more than 110° F, plus a bright sun beating down, can result in effective environmental temperatures exceeding 140° F. Under such dry, hot conditions, a human would require at least ten quarts of water a day, but red kangaroos can easily get by with one drink of two to three quarts every week or two. By hunching up under a desert tree or shrub, with its large tail pulled forward between its legs, the animal reduces the surface area exposed to the sun. Blood flow to the surface of the skin (except to the forelegs) is also shut down on hot days, further increasing the body's insulation.

Is the red kangaroo's existence threatened, as has been the case with so many Australian native mammals? Generally, it seems to be comfortably holding its own. In some areas, like the rangelands where sheep graze, red kangaroos have actually benefited from human intervention. Sheep ranchers have put out watering troughs in isolated areas, controlled predators (especially dingoes), and cleared scrub to promote the growth of grass—all of which are helpful to red kangaroos. In some of the lusher areas of its range, however, the red kangaroo is being displaced by two species of gray kangaroos, which originated in the wetter coastal and forest regions. Because gray kangaroos are profligate in their water use compared with red kangaroos, they can thrive only in areas where watering troughs have been placed for sheep. With provisioned water, the grays can range more widely and gather more food. Because they give their young much longer parental care (eighteen months compared with twelve months for the red kangaroo), a higher proportion of the grays' young are likely to survive. Their dependence on ample water, however, has prevented gray kangaroos from penetrating into the central deserts.

Regulated harvesting of red kangaroos has had little effect on their numbers. When older animals are removed at the level permitted by wildlife authorities, more of the youngsters tend to survive and replace them in the population. With large areas of its range being set aside for national parks, the red kangaroo, with its superior adaptations to dry country, appears secure for the present. ☐

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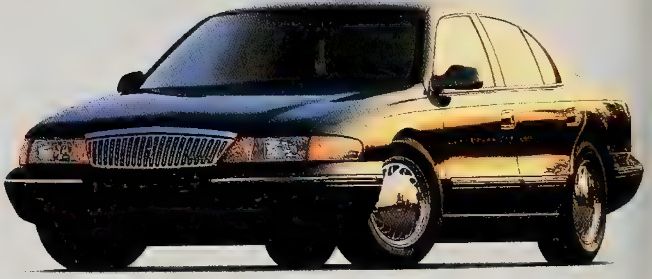

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The Serpent's Tongue

A snake's forked tongue keeps it from winding up on the wrong side of the tracks

by Kurt Schwenk

On a windswept California hillside, amid the parched grass and live oak, a western rattlesnake waits. Coiled beneath a rock overhang, its scaly skin and muted tones blend with the grass, earth, and stone. Lidless eyes stare, transfixed; the snake's only movement is the occasional flicker of its forked tongue. Ever vigilant, a ground squirrel hesitantly approaches in search of food. Imperceptibly, the snake's body tenses, slitted pupils shift, the accordionlike folds of the front third of its body prepare to extend. The squirrel—moving, stopping, moving, stopping—draws nearer. When the squirrel is within reach, the snake straightens explosively, hurling itself at the still unaware animal.

As it traverses the short distance between itself and the prey, the snake opens its mouth and erects its formidable fangs. Too late, the squirrel sees the snake and stares death in the mouth. It is thrown backward by the impact of the snake's head, impaled by the fangs, and poisoned deep within its core. The rattlesnake releases the squirrel and, after the concentrated fury of its attack, seems strangely unconcerned as the squirrel runs off in panicked flight. The squirrel soon slows, for each bound has pumped the poison farther and farther through its system. A witches' brew of enzymes and other compounds, the venom has already begun the process of digestion within the body of the squirrel. Now, fifty yards away, the doomed animal seeks refuge within the hollow of a log, where its labored breathing soon ceases.

Slowly at first, the snake moves off. Its tongue extends and retracts constantly, its oscillations a blur. With each flick, the tips of the forked tongue splay, and just before their retreat back into the mouth, they gently brush the ground. With no hesitation, the rattlesnake glides through the grass and among the stones, moving directly toward the hollow log, as if it had known all along where the squirrel would go. Only once does the snake pause, swinging its head back and forth while flicking its tongue. Then it again moves along the ground to the log and the still warm body

Prey's eye view of an African bush viper sampling the air with its tongue
Brian Kenney

of the fallen squirrel. Nudging the body with its snout, the snake finds the squirrel's head and begins the long process of engulfing a food item nearly half its own weight. Mobile jaws pull the snake's mouth over the squirrel's body, like a glove over a finger, until, at last, peristalsis and a final, sinuous curve of the snake's neck push the squirrel into the snake's stomach, where the process of digestion will continue. Activity of the venom insures that the squirrel will be digested before it can putrefy and poison the snake. Safe within the log, its modest energy demands satisfied, the snake will not hunt again for several weeks or months.

This drama is enacted daily, in one form or another, around the world by almost 3,000 species of snakes. And while we may be predisposed toward sympathy with our hapless mammalian cousin, we must admire, however grudgingly, a snake's amazing ability to locate, identify, dispatch, and then relocate its furry victim. Pitted against the prey are the snakes' diverse sensory systems: acute vision in most species and color vision in some; hearing that is particularly sensitive to low-frequency sounds, such as groundborne vibrations; the chemical sense of smell; and in some species, such as rattlesnakes and large constrictors, heat receptors. However, by far the most important and exquisitely sensitive sensory mode employed by all snakes is another and less familiar chemical sense akin to smell, known as the vomeronasal system. Snakes inhabit a world richly textured in chemical cues that guide the animals in the most fundamental activities of life, from finding food to locating potential mates.

At center stage in this drama is a remarkable little organ as mysterious as it is feared—the serpent's forked tongue, a symbol of malevolence and deceit. Images of forked tongues appear in ancient pictographic scripts of Mesopotamia and China, petroglyphs of East Africa, and the religious iconography of cultures as diverse as the Aztecs, the Siberian Altai, and the Sumerians of Babylonia. Early naturalists, such as Aristotle, discussed the forked ophidian tongue. Indeed, snakes and their forked tongues are so deeply embedded in our collective psyche that I was surprised to learn that an obvious question had not been fully answered—why are snakes' tongues forked? Such questions are the bread and butter of evolutionary morphologists like me, and as someone

John Cancalosi

Having injected a wood rat with venom and then used its own sensitive forked tongue to follow the trail of the fleeing but doomed animal, a western diamondback rattlesnake opens wide to swallow its prey, left. Below: A nonvenomous gray rat snake seems to grin as it stretches to accommodate a bird egg. The dark opening at the base of the snake's mouth is the glottis (the end of the trachea). While eating, the snake retracts its tongue into a sheath beneath the trachea.

Jim Merli; Valan Photos

who specializes (I hesitate to admit) in the anatomy, function, and evolution of tongues, I thought that I should know the answer. In finding it, I learned not only about snakes but also something about the nature of scientific progress.

Unlike the rather obscure bits of anatomy that I usually ponder, the conspicuousness of snake tongues has made them a source of speculation over the years. Recorded inquiry into their function begins, as for most things scientific, with Aristotle, who reasoned from the basis of his own tongue that the fork provided snakes "a twofold pleasure from savors, their gustatory sensation being as it were doubled." Hodierna, a seventeenth-century Italian naturalist, thought that snakes used the tips of the tongue "for picking the dirt out of their noses, which would be apt else to stuff them, since they are always groveling on the ground, or in caverns of the earth." Many are convinced that the tongue is a stinger, particularly in venomous species, and others claim to have witnessed the capture of flies between the tongue tips. The reigning scientific view during the first part of this century was that tongue flicking and the delicately forked tongue were part of a tactile mechanism, giving snakes a sense of fine touch.

Unfortunately, these colorful, and even plausible, explanations of forked tongue function can no longer be accepted. Aristotle's idea, like our sympathy for the squirrel, is based less on science than on anthropomorphism. But unlike us and even their lizard kin, snakes lack taste buds on their tongues and are singularly depauperate in gustatory pleasure. And although I appreciate the symmetry expressed in Hodierna's hypothesis (two nostrils, two tongue tips), I have spent a lot of time watching snakes, and I have never seen one with its nostrils blocked with dirt nor with its tongue in its nose. Likewise, the stinger and flycatcher ideas are without basis, and the frequent flicking of the tongue into the air, contacting neither ground nor object, belies its role as a tactile organ.

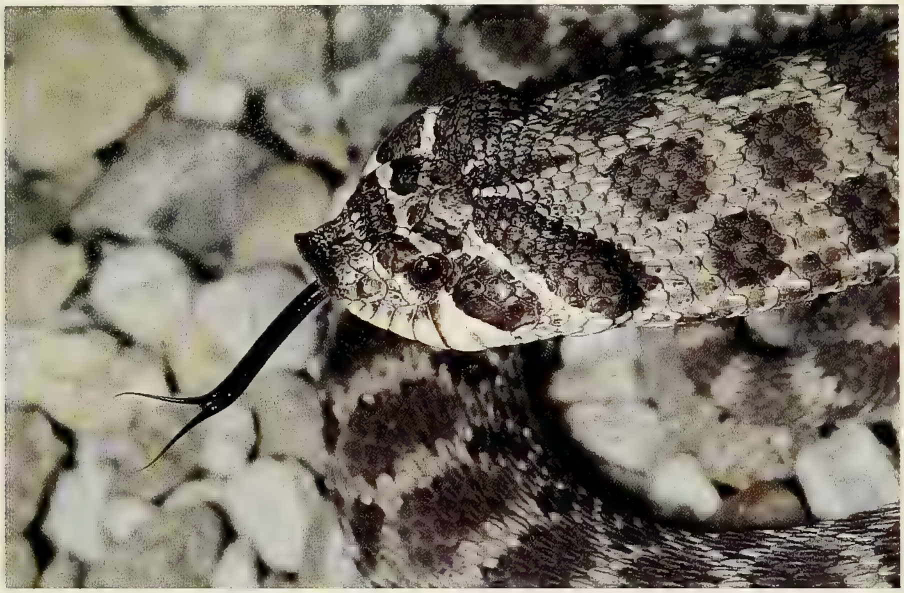
In a series of elegant experiments conducted in Germany and the United States during the 1920s and 1930s, the first scientific clues to the function of tongue flicking in snakes were revealed and led directly to new ideas on the function of the forked tongue. Experimenters showed that the key to tongue flicking is found in two tiny organs that lie side-by-side in the snake's snout just above the roof of the mouth. Named Jacobson's organs after their discoverer, they are now usually referred to as the vomeronasal organs, or VNO. These small, bulb-shaped structures develop as an offshoot of the nasal cavity, becoming isolated from it and forming separate connections to the mouth through openings in the palate.

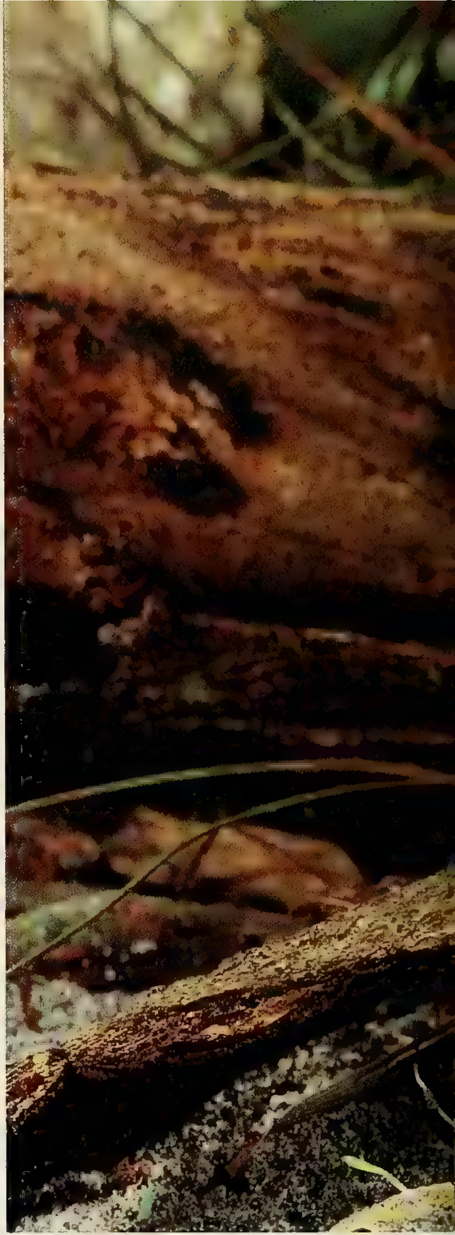
Each VNO contains its own small patch of sensory cells. These cells have nerves that connect them to the olfactory bulb of the brain, although not to the same part of the bulb that is connected to the sensory cells of the snake's nose. What the experimenters discovered was that tongue flicks deliver chemical particles into the mouth that make their way up through the openings and into the VNO, stimulating the sensory cells. This equips snakes (and their close cousins, the lizards) with a chemical sense similar to smell, but differ-

Joe McDonald; Bruce Coleman, Inc.

All snakes, including the nonvenomous hognose snake, below, and some lizards, such as the Dumeril's monitor lizard, right, use the sensitive tips of their forked tongue to follow scent trails of prey or potential mates. Providing a sort of "stereo smell," the tips enable the animals to stay on track.

Harry W. Greene





ent and distinct. Although many mammals and other vertebrates also have a VNO that they stimulate through various means, we humans are as lacking in this vomeronasal sense as snakes are in taste.

Although it was established that the tongue delivered odor particles into the mouth, the mechanism of particle transfer to the VNO remained unknown. In the 1920s, some German researchers suggested that the slender tips of the forked tongue must be inserted *into* the openings of the VNO, delivering scent particles directly. This hypothesis was so elegant that it was almost immediately accepted and eventually became dogma.

The only problem with the theory is that it is contradicted by the evidence. Some of the earliest experiments, performed by German workers in the 1930s, demonstrated that snakes could deliver particles to the VNO even when their tongue tips had been surgically removed. Later that same decade, German and American researchers pointed out that most lizards have only notched tongues with blunt tips, hardly capable of being inserted into the tiny openings of the VNO, yet they too flick their tongues and stimulate the VNO as effectively as snakes. Recently, Brent Graves, of Northern Michigan University, and Mimi Halpern, of the Downstate Medical Center in Brooklyn, have experimentally verified these findings.

Film and X-ray studies have provided further evidence, showing that the tongue tips are not inserted into the VNO and that—at least in snakes—pads on the floor of the mouth, and not the tongue directly, probably deliver the scent particles to the openings in the palate. As the tongue is retracted into its sheath, its tips brush along pads in the floor of the mouth. These pads are then elevated and pushed against the palate and VNO openings.

As strong as the evidence against it has been, the tongue-in-VNO explanation of forked tongues has had a significant impact on modern studies of snake and lizard chemoreception and can still be found in some textbooks. Such is the power of dogma.

A firm believer in the fruits of the unconscious mind and nonlinear thought, I was treated to one of the creative high points of my professional career one day when a colleague asked me why snakes have forked tongues. In that moment, years of miscellaneous thought on tongues and the VNO suddenly seemed to gel and the answer to his question became clear. What I realized was that the years of concentrating on how forked tongues *deliver* scent particles to the VNO had distracted us, like the proverbial red herring, from their true function: namely, *sampling* those scent particles from the air or the ground in the first place.

Like paired ears or paired eyes, a forked tongue could provide a kind of "stereo smell" that would give snakes the ability to sense not only the presence of some chemical but also its location. If this were true, the snake would have to be able to sample scent particles from two different points (via its two tongue tips) and assess whether there was a difference in the strength of that chemical on the left side versus the right side. This ability would be particularly useful for following pheromone trails left by other animals. I ran to my office, where I set about the painstaking task of supporting or refuting my new idea.

What I discovered shocked me: I was not the first to have this idea. Indeed, it had

been proposed independently two times in the previous thirteen years. In the first case, Walter Auffenberg, of the University of Florida (now emeritus), had intuited the theory during the course of his classic study of the Komodo dragons of Indonesia, fork-tongued lizards related to snakes. He observed the lizards' remarkable ability to follow invisible scent trails of prey animals, all the while flicking their deeply forked tongues. Similarly, Neil Ford, of the University of Texas at Tyler, had studied how male snakes follow pheromone trails left by passing females. He noted that the tips of the forked tongue would spread far apart and brush the ground before being retracted. As long as the tips stayed within the confines of the trail, the snake moved directly along it. When one tip overstepped the edge of the trail, the snake turned back. When both tips left the trail, the snake stopped, swung its head back and forth, and tongue flicked until it relocated the trail and resumed its travel. Both Auffenberg and Ford proposed that following scent trails was the function of the forked tongue for finding both food and mates. Mimi Halpern and her colleagues had already shown that the ability to follow scent trails is a hallmark of snake chemosensory biology.

When I tested these ideas, I found that virtually all observations were consistent with the trail-following function of forked tongues. Indeed, the earliest experiments involving surgical removal of the forked tongue tips had shown only one behavioral deficit in the treated animals: loss of the ability to follow trails. The brain circuitry of the vomeronasal system in snakes is set up to provide the ability to compare chemical signal strength from left and right sides. Slow-motion films revealed that both snakes and fork-tongued lizards spread their tongue tips far apart just as they touch the ground, apparently to maximize the likelihood of picking up a difference in chemical strength between sides. When access to the VNO on one side was blocked, a snake attempting to follow an odor trail turned consistently toward the strong, unblocked side—and as a result, simply made a circle.

How might this remarkable organ have evolved? Tongues are composed of soft tissue, so fossils are of little help. Comparisons among living species, however, can provide indirect clues to evolutionary history. Since all living snakes have forked tongues, little can be learned by examining them alone, so I began by comparing snakes to their closest living relatives, the lizards. We now believe that snakes evolved directly from a group of lizards whose modern members include the Gila monsters of the Southwest and the moni-

Wolfgang Bayer; Bruce Coleman, Inc.

Its heat-sensing pit clearly visible, a black-tailed rattlesnake spreads its tongue tips wide and stares ahead, all senses acutely tuned to its surroundings. Their diverse senses make snakes, venomous or not, formidable predators. The emerald boa, right, having surprised an unfortunate Amazon parakeet and constricted it, causing its rapid death by shock, hangs from a branch while embarking on the lengthy process of swallowing.

Joe McDonald

tor lizards of the Old World. Within that group, I found that tongues ranged from only slightly forked to the snakelike tongues of the monitor lizards. By widening the comparison to include all lizards and considering an evolutionary tree of this larger group, I discovered that deeply forked tongues had evolved at least one other time, in another group of lizards.

Adding information from behavior and ecology to the analysis, I found a tight correlation between the presence of a forked tongue and the ability to follow scent trails, and that each time forked tongues evolved in lizard/snake history, so did the behavior of searching widely through the environment for food or appropriate ambush sites. Lizards that do little searching, simply waiting for food to come to them, lack forked tongues.

Returning to our rattlesnake, we can now appreciate its abilities more fully. While exploring its environment, the snake frequently flicks its tongue. At some point, it crosses a pathway used by small mammals and other animals. Among the many scents it detects is the odor of a female of its own species, but the rattler discerns that she is not in mating condition and therefore not worth following. It next detects the fresh scent of a desirable prey species. (Gordon Burghardt, of the University of Tennessee, has shown that most snakes have an innate ability to discriminate prey from nonprey.) Its search ended, the snake chooses a hidden spot within striking distance of the trail and awaits its next meal. The passage of a hiker and then a fence lizard elicits little interest other than a flick or two of the tongue, but the arrival of a squirrel triggers its predatory instincts.

The rattlesnake's strike results from the complex interplay of visual, chemosensory, and thermal cues emanating from the squirrel. At the moment of impact and envenomation, the rattlesnake learns the scent of this individual animal, which it will then prefer over all others, as discovered by David Chiszar and his students at the University of Colorado. Hence, the snake is unconcerned about letting the squirrel go. By releasing the squirrel, it needn't fear any retaliatory bite, and it can let the squirrel's own muscle contractions and circulatory system distribute the digestive venom. Now, with the use of its forked tongue to monitor the chemical trail left by the squirrel, the snake easily tracks the animal to its final resting place within the log. There, tactile cues from the squirrel's fur direct the snake to the head for easier swallowing of so large an animal. Being ectothermic (cold-blooded), the snake needn't squander calories on generating body heat, and having eaten so large a meal, it will not have to feed again for many weeks.

These skills are applied by venomous and nonvenomous snakes. In each case the forked tongue plays an essential role. In many ways, the tongue and the tremendously sensitive vomeronasal system it serves are the essence of being a snake. The forked tongue symbolizes, not duplicity, but evolutionary success, for this marvel of engineering may have helped snakes become what they are today—one of the most successful radiations of land vertebrates alive on Earth. □

Shouldering his bow, a Yanomami teenager goes hunting.
Nick Nichols; Magnum

The Yanomami Keep on Trekking

In Amazonia, a break from gardening makes for a balanced diet

by Kenneth Good

Bë kuami! "They are not home!" I remember my disappointment as I arrived at empty village after empty village on my month-long expedition. I had started out from the Yanomami community of Hasupiwëteri, on the upper Orinoco River in the Venezuelan Amazon, with the goal of reaching the banks of the Parakeet River, thirty-five miles to the south. It was 1976, the second of twelve consecutive years that I would live with the Hasupiwëteri at their changing locales. I and five of their strongest young men had set off with food, gear, and gifts to contact the scattered inland villages. No nonindigenous outsider had ever made this trip overland, through the hilly terrain covered with dense forest, although one group in the area had been visited once by helicopter. None of the Yanomami from my community had penetrated that far either, although some had reached the closest villages and knew by word of mouth of the others.

We had spent three days pushing along little-used trails barely visible to the inexperienced eye. One day out, we had visited the first village, but after that we had encountered no one. The third day had been especially difficult, as we chopped and hacked our way through an old, abandoned garden during a torrential downpour. I realized then why the Yanomami are "pioneering horticulturists," always planting their gardens in virgin forest. Who would want to reclear this snake-infested tangle of thorny brush? Beyond the garden we began the last of numerous ascents in the rolling hills to the community of Ashitowëteri. As we neared our destination, my excitement peaked. My guides told me we had reached the last stream before we would arrive, and as is the Yanomami custom when visiting another village, we stopped to bathe.

After a brief, refreshing dip we hurried down the trail until we arrived at the village gardens. Bananas and plantains in various stages of growth made up about nine-tenths of the well-tended vegetation. Off to one side we saw a few *ohina* root and manioc plants. Some cotton bushes and a couple of avocado trees were the only other visible crops. After several hundred yards, we were out of the gardens and standing before one of the largest and best-constructed communal shelters I had seen. But it was empty.

The Yanomami are what anthropologists call horticulturists, or gardeners. Although a large and important part of their diet consists of foods from hunting and gathering, they also grow plantains and bananas, using simple tools and a clearing technique known as slash-and-burn. Their crops enable them to live a more sedentary life than full-time hunter-gatherers, who have to follow their food as it becomes available in the forest. Their communities are larger and their homes and personal possessions are more elaborate. So where were the horticultural Yanomami of Ashitowëteri when I arrived to pay my repects?

I realized that there was only one thing they could be doing: they were on a *wayumi*, a trek in which the entire community packs up its possessions, abandons the communal shelter, and takes to the forest in one or several groups to hunt and gather wild foods. I already knew about the treks. It takes at most a few months' residence with the Yanomami to become familiar with them. But I could not contain my frustration at finding no one at home, and my feelings were shared by my Hasupiwëteri friends. While I wailed, "Why do they have to go trekking now?" my guides heaped scorn on our absent hosts, calling them peccaries for spending their days foraging in the forest.

Another frustration of arriving at an empty village is missing out on a good meal. When one travels long distances

A Yanomami hunter takes aim, probably at a bird. Game is a chief source of protein.
Victor Englebert

Victor Englebert

Ripe plantains, below, the Yanomami's main cultivated crop, are peeled for a feast. In the communal house, right, a family's hammocks are strung close together so that they can share the heat from their hearth during the cool night. Bottom right: Women carry manioc from a garden.

Kenneth Good

across the forest, the intermittent stops are critical for keeping up energy levels. Now we were forced to take what we could from the garden and pay for it another day. While the other men checked the trails to determine when the residents had left and in which direction, Karisi and I collected food from the Ashitowëteri gardens. Fortunately, on our way back after visiting several other empty villages, we came across the Ashitowëteri at one of their temporary camps. We showered them with our gifts—machetes, knives, and other desirable items—more than reciprocating for the food we had taken. It was the first of my several stays with this previously uncontacted community over the next ten years.

Not long after we returned to Hasupiwëteri, that community also determined to go trekking. While we had been away, the able-bodied men had gone on a hunt. They were planning to invite another village to a funeral ceremony, and meat was a major requirement for the event. The hunt had failed, as many of them do, and after our return they made a second attempt. They returned with white-lipped peccaries and some small game. The hunters were happy to bring back such a quantity of smoked meat, even though out of a herd of more than fifty peccaries, a force of thirty-two hunters succeeded in bringing down only three.

When I awakened the morning after the feast was over, preparations for the trek were already under way. While the last few mature plantains from the garden roasted on the family hearth, men and women were packing all their possessions in bundles. Using a tumpline, the women bear the burden of portage, sometimes carrying loads of more than 100 pounds—plantains, aluminum pots, axes, hammocks, and even a child. Quickly I got out of my hammock and began organizing my own equipment and necessities (many supplies could be left behind, stashed in locked trunks). Fortunately, I could arrange for four young men to help carry my possessions.

While the women were still packing, the men marched out of the village, anxious to start down the trails before the animals were scared off by the larger group. Most carried little more than their bows and arrows, so they would be unencumbered for any hunting opportunity. Burdened as they are, the women and children move very slowly and rarely cover more than a mile in a day. The men periodically stop and wait for them to catch up.

After only a few hours, still before noon, the men began to make camp for the night. Each cleared a small area, and in no more than half an hour erected a simple frame for the family shelter. Most then disappeared into the forest to hunt. When the women arrived, they cut *platanillo* leaves and covered the roof frames prepared by their husbands. After setting up house by hanging their hammocks, gourds, and other belongings, they took to the streams to crab or to the forest to gather wild foods.

Our trek lasted five weeks. If there was a large stand of food near a campsite or if hunting proved productive, the community would spend several nights there. Otherwise, they would pack up their belongings at daybreak, bundle the leaves from the roofs, and move on to another

site. Men, women, and children, the old and the infirm moved through the forest, exploiting Amazonia's varied wild foods. In addition to the skill with which the Yanomami hunted and gathered, the ease with which they trekked reinforced my view that this was an ancient pattern of livelihood.

As I accompanied this trek and many more over the years, I kept detailed records of the Yanomami's activities, especially those related to food and nutrition, the subject of my research. The same thought was always on my mind: "Why do they trek?" Probably underlying my question was the ethnocentric notion that social progress consists of having a settled life, and that trekking is a kind of enforced hardship to acquire food in lean times. The Yanomami see it differently, however. For

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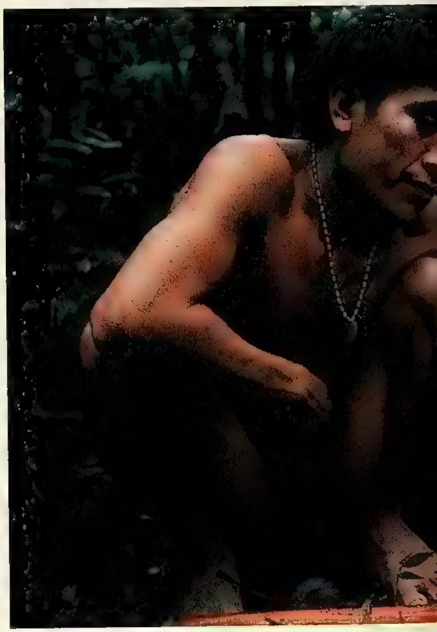
them the trek is a welcome event, one that raises the spirits. Trekking takes the community to fresh, cool forest areas that have not been exploited for a long period, perhaps not within living memory. Nevertheless, the question remains: Do the Yanomami really need to go trekking?

At first glance, the reason the Yanomami trek seems to be that they run out of mature plantains from their gardens. Plantains and bananas were most likely introduced into the New World by the conquistadors. Scientists generally believe that in pre-Columbian times, the Yanomami were hunters and gatherers and that they continue to trek because their forager culture has failed to make maximum use of agriculture. So why don't they just grow more plantains?

Decades ago, anthropologist Robert Carneiro, of the American Museum of Natural History, demonstrated that there is no environmental limitation in Amazonia on growing sufficient crops for a village to remain sedentary. My own studies of forest areas around the Yanomami communities confirm that there is almost always land suitable for expansion of cultivation. The men, who do all of the garden work, spend an average of less than two hours per day preparing the gardens. They could easily double that time without significantly changing their other activities. But they don't.

Instead, the Yanomami apparently take into consideration that they will trek and, therefore, plant no more than necessary for several months' supply. In fact they spend an average of 40 percent of the time in the forest trekking, and in some cases as



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Kenneth Good

A woman carries a load of firewood, left, into a temporary camp set up during a hunting-gathering trek through the forest. Another woman, below, sets out on a trek with all her household possessions. Bottom left: Primarily used to hunt monkeys, curare-tipped darts are dried over the fire.

Kenneth Good

much as 60 percent. The underlying practical reason seems to be that plantains (or manioc, in the case of other Amazonian tribes, such as the Kayapó) are rich in vitamins and minerals but have very little protein. Lacking a more balanced range of crops and domesticated food animals, the Yanomami must get their meat and fat as they have always done, from the wild animals of the forest.

Amazonian game species are relatively small and elusive, and hunters often fail in their quests. Even with this poor hunting record, when a village stays in one place for a long period of time, the local animals are quickly depleted. One way to compensate for this is for the men to leave their families and gardens and go out on long-distance hunts. Camping in the forest, with minimal food, they hunt from dawn to dusk for up to a week. Trekking, however, offers an alternative that keeps family members together and allows long-term exploitation of other forest areas. My studies show that on treks, hunting yields are double those near the garden location. Consumption of wild foods increases from 10 percent to almost 70 percent. (The diet still includes some crops, retrieved from the gardens during the early and late stages of the trek.)

While the group is out trekking for weeks or months, the young plantains in the gardens are maturing. When the wild foods become harder to obtain, the trekkers begin their return. They may even say that they get tired of wild foods and that their minds turn again to plantains. The truth is that they must go back. They cannot subsist year-round as hunter-gatherers because the domesticated crops have allowed their average village populations to grow to sixty or seventy. Wild foods are too dispersed to feed so large a group, even for one or two nights. But neither can the Yanomami be full-time farmers, because adequate protein is not provided at the garden sites.

Apart from fulfilling nutritional needs, there are other advantages to trekking. As a village grows larger, quarrels are more likely to erupt in the community. For example, even a large game animal does not yield enough meat for all the families. Meat is the only item in Yanomami culture that is shared village wide. To be slighted in the distribution causes very intense feelings. When such tensions reach a peak, the

A Reputation for War

by R. Brian Ferguson

Ever since they were dubbed "the fierce people" by anthropologist Napoleon Chagnon in the 1960s, the Yanomami have typified primitive belligerence for hundreds of thousands of college students. The groups Chagnon lived with on the upper Orinoco River seemed endlessly embroiled in fights, duels, and treacherous raids, as the men competed over women and status or sought to avenge previous killings. The vivid descriptions of Yanomami character and warfare helped fuel a debate over whether humans were inevitably propelled toward violence. The debate was largely precipitated by Robert Ardrey's popular book *African Genesis* (1961), which argued that humans had a genetic heritage as "killer apes." Many academics countered that, far from being instinctive, warfare would have played a minor role throughout most of the human evolutionary career. They tied the advent of warfare to the agricultural revolution, with its sedentary communities and stores of food, and the subsequent rise of centralized states. Human nature, they declared, was almost by definition plastic, shaped by culture, and humans could be educated to solve their conflicts in other ways. Against the background of the Vietnam War, this was a more optimistic message.

Enter the Yanomami, a people apparently isolated from outside influences until recent times. They were proclaimed by some to be the living embodiment of a violent evolutionary heritage. Others, rejecting this grim interpretation, sought an adaptive explanation for Yanomami behavior. They proposed that in the tropical Amazonian forest, which lacked rich concentrations of resources, warfare and hostility served to break up groups into sustainable size and then space them suitably across the landscape. In this view, although warfare had its costs, it contributed to the Yanomami's ability to survive within the limitations of their ecosystem.

Both of these interpretations took for granted that the Yanomami way of life was pristine. But my historical studies, comparing the experiences of many different Yanomami groups, have led me to reject that view. I have found that these Amazonians have been affected by the presence of European Americans for up to 350 years, and that Yanomami warfare can only be understood in this light.

Outside influences began in the 1630s, when Portuguese, Spanish, and Dutch colonists, or their indigenous allies, came raiding for slaves. The ensuing violence wiped out the more complex societies that had existed in the Yanomami region—densely settled chiefdoms of river traders—and restricted the Yanomami to highland sanctuaries. Both peaceable and violent contacts between Yanomami and outsiders occurred from the mid-eighteenth century until 1950, when the first Protestant mission settled in alongside a Yanomami village, initiating extensive interactions that still continue.

When the political history of Yanomami living in various parts of their territory is reconstructed, a connection emerges between their wars (with one another or with neighboring peoples) and significant changes in the European American presence. The common thread in their fighting appears to be access to, and control over, sources of Western trade goods. Like other Amazonian groups, the Yanomami have rapidly come to regard steel tools, aluminum pots, cloth, and other manufactured items as necessities. Yanomami able to obtain these goods close to the source want them not only for their own use but also to trade with groups farther away. In exchange, other Yanomami provide local products, labor, wives, and political support. Friction arises because the interests involved in these exchange relationships are so vital and the inequalities are so pronounced. This friction can lead to raiding, directed at protecting or improving positions within the radiating trade networks.

In the first decade of this century, for example, the frenzied rubber-tapping boom in Amazonia led to a surge in Western trade goods passing along the Uraricoera and other rivers near Brazilian Yanomami territory. In a series of raids, ambushes, and at least one pitched battle, some local Yanomami groups carved out a niche in the trade system. They then gave up raiding, but soon were pressed from behind by the "wild" Yanomami in the mountains.

For some Yanomami, including those living around the mission posts of the upper Orinoco River, contact with resident outsiders has led to a much more sedentary way of life. Over time, hunting depleted

An adulterous affair caused two men to fight each other with clubs.
Kenneth Good

:al game supplies and was replaced by hing, more intensive cultivation, and nsumption of mission foods. Having lost :ir mobile way of life, these groups are able to follow the traditional option of oving away when frictions arise. And th little hunting, they lose the custom of aring meat, which as Kenneth Good has served, is a source of solidarity. Worst of , their exposure to outsiders brings them w diseases, with epidemics tearing great les in the social fabric. For some Yano- ami, such as those encountered by iagnon, long and strong contact with the tside world created so much disruption at, for a time, violence became almost rmal in interpersonal relations.

The Yanomami case shows the extraor- nary reach and transforming effects a ntrally governed society, or state, may ve, extending way beyond its last out- st. The impact of disease, trade goods, igrations, and political restructurings can read far in advance of face-to-face con- ct, and when the state's advance agents arrive, they commonly bring even more struction with them. Because they may ssess firearms or dispense coveted trade ods, even contemporary missionaries d anthropologists can become important ayers in these conflicts and the focus of olent competition. That is what hap- ned on the upper Orinoco.

The changing economic and political nditions in a remote "tribal zone" can ad to bloodshed, sometimes creating arfare in regions where little or none ex- ted in the past. For centuries, Westerners ve looked upon such carnage and used it justify the obliteration of indigenous ltures in the name of civilization. What s not been acknowledged is that the avage" behavior is itself often a result of reign intrusion; that local conflicts are mly connected to global processes. The anomami have taught us to proceed with treme caution before assuming warfare indigenous groups is pristine and iso- ted. Anthropologists can lead the way in plying this important lesson to so-called hnic or tribal warfare in Africa and urope.

. Brian Ferguson, an associate professor anthropology at the Newark campus of utgers University, is the author of Yano- ami Warfare: A Political History *(Santa e: SAR Press, 1995).*

Hunters cut up a peccary for distribution. The sharing of meat, a coveted food, is a traditional source of community solidarity.

Victor Englebert

village can split, with each faction going on its own trek in a different direction. This separation allows for a cooling off of emotions.

Splitting up also makes for a better return on foraging. While today fifty or sixty Yanomami may trek together, most likely in the past, when they were full-time hunters and gatherers, they would have had to restrict their group size to a maximum of twenty or twenty-five. In a smaller group, the killing of a large animal will provide each family with a larger and more choice piece than would be possible if the entire community were living together. The increased supply is especially welcome because the Yanomami normally get to eat meat only twice a week and usually in very small portions.

When a large village splits up on the trek because of internal friction or because the group is simply too large to travel together, one group of families may begin new gardens at a distant campsite. On subsequent treks, the gardens will be expanded, and when they begin to produce crops, the families move there, eventually constructing a new communal shelter. In this way a village splits permanently, dealing peacefully with problems of disharmony and an inadequate supply of food, especially meat. Otherwise these problems can lead to a violent fission.

Trekking can also have a downside. When a community returns to its gardens after an extended stay in the forest, it sometimes finds that other Yanomami, also on trek, have made their way to the untended gardens and eaten the newly matured crops. This results in a severe food crisis for the returnees, and on occasion, hostilities develop between villages. These may take the form of a chest-pounding match (opponents take turns slugging each other in the chest), a club fight, or even a raid. In the case of a raid, trekking also has a role to play. When raiders return home after attacking another village, they and the rest of their community often leave on a trek to avoid becoming sitting ducks in a revenge raid.

More than 95 percent of the Yanomami still live in their traditional deep-woods environment. But a few communities that have settled along rivers have adopted new ways of making a living, made possible by access to manufactured goods from traders or from a Western settlement. These Yanomami spend less effort on inland hunting. Instead, fishing takes on

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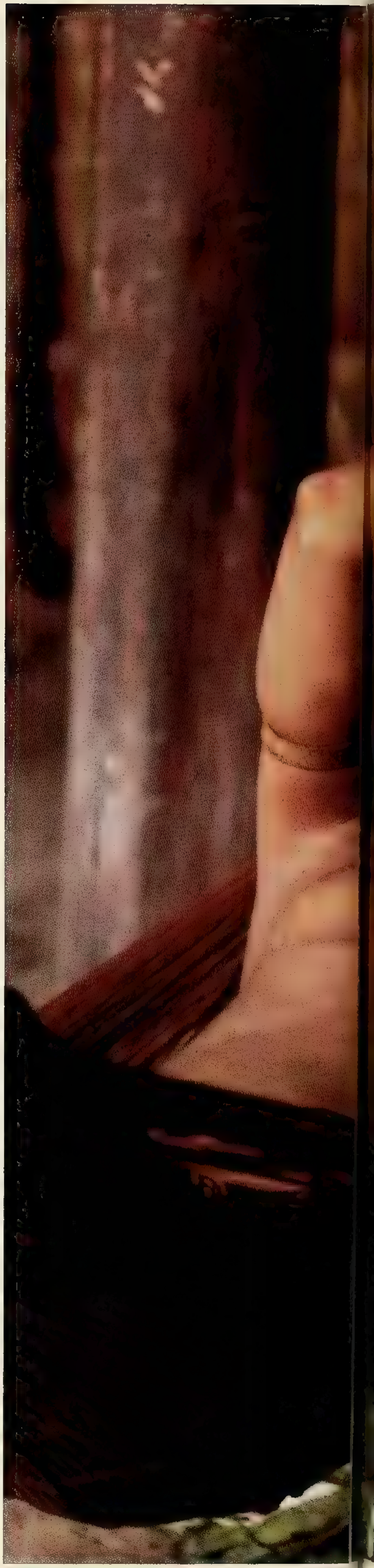


greater importance, the men taking to the rivers in canoes. They use manufactured hooks and lines, often fishing at night with lights acquired through trade or labor. Once they acquire or learn to make dugout canoes, they can fish over a greater range without moving the communal shelter or trekking. Watercraft are also used to add to the number of areas where gardens can be cleared, maintained, and harvested. They often use areas across the river from the settlement for gardening and hunting.

Yanomami river settlers grow larger gardens, aided in part by the greater availability of steel axes and machetes for forest clearing. They also learn from outsiders how to grow and process other foods besides plantains. Most common are cassava bread and manioc meal, both of which can be stored for use when plantains are not abundant. As a result, these communities engage in fewer treks; some have discontinued the practice altogether.

While the river settlements may have benefited from manufactured goods, Yanomami communities along the Venezuelan–Brazilian border have been devastated by outside contacts. A Brazilian policy of opening this area to settlers, cattle ranchers, loggers, and gold miners has resulted in the poisoning of rivers and streams with byproducts of gold processing and the stripping of thousands of acres of forest for logging and pastures. An international outcry has provoked some government effort to halt this activity, but control of these very remote areas has been spotty at best. As a result, the Yanomami who live there have been deprived of the forest they use to feed themselves.

In 1993, the conflict of interests resulted in tragedy. With their large stores of steel tools, clothing, medicines, shotguns, and shells, Brazilian gold-mining camps in Yanomami territory had become a major attraction to nearby villagers, particularly the young men. The miners found the Yanomami's persistent requests for goods a great irritant and even threatened to respond with violence. The friction came to a head when a group of miners, annoyed by the requests, as well as by a demand that they return a confiscated shotgun, decided to kill the young men. Encountering them on the trail, they shot several of them execution-style. After a series of retaliatory raids by the Yanomami, the miners raided the village, killing about twelve. Those shot included men, women, and children, some of whom were hacked, dismembered, and decapitated with machetes after being gravely wounded.

A pet bird, below, receives a morsel of banana. Right: A couple relax in their hammocks.

C. S. Perkins; Magnum

Perhaps it is unrealistic to hope the Yanomami will be allowed to continue living by their traditional culture. But more is at stake than whether they will be absorbed culturally by the surrounding societies. Their very physical survival is in jeopardy. As national governments open up the tropical forests to development, the Yanomami will be pushed off the land. Already their rivers and streams are being polluted, while the animals they hunt for critical protein are being driven away by machinery used in lumbering and mining. Intensified by outside contact, malaria and respiratory diseases are also taking a toll. If these trends continue without restrictions, the Yanomami will die out. Their destiny is ultimately in the hands of those who have come to control the lands where the Yanomami have trekked for so many generations. □

Belly Up to the Bar

This round's on me

by Roger L. Welsch

Why is my room square? Why are our buildings retangular? Why are round beds not only peculiar but maybe even a little kinky? Why is a boxing "ring" square? (Ah, the wisdom of children with their round marbles and circled arena!)

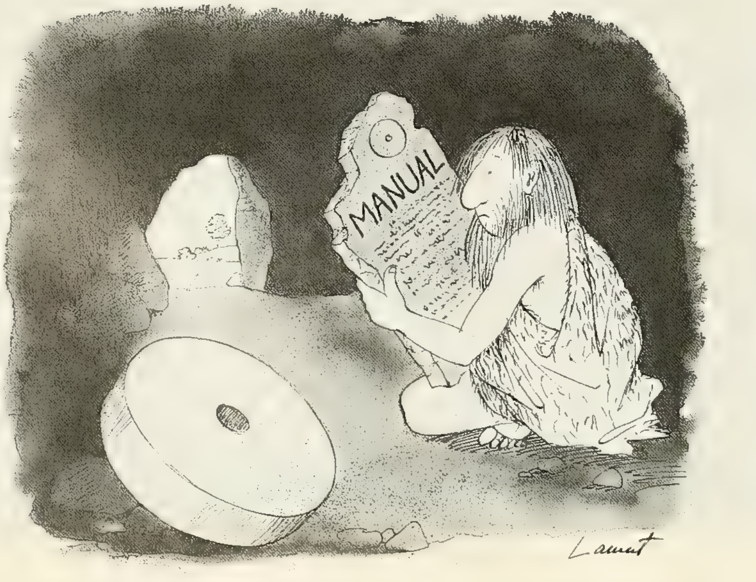
I first became interested in the question of round versus square thirty years ago while examining Plains folk architecture. I was fascinated by the advantages of the Gothic barn roof as opposed to the gabled or hipped roof—less material, more open space, lines more suitable for piles of hay, more strength. I wondered why there weren't more Gothic roofs on barns. Maybe why there weren't *only* Gothic roofs.

There were also round barns, remarkable and beautiful—in part because their interiors are so open, so uncluttered by braces and supports. Round construction, it turns out, takes less material for the same amount of area and volume. It is stronger and more efficient, more attractive, more logical.

Also during my work with century-old barns, I encountered the original meaning and wisdom hidden in the expression "a square peg in a round hole." Today that phrase refers to someone (a square peg) who is out of tune with things around him (the round hole). Someone who is unqualified, who doesn't fit. Someone who makes things difficult.

Back in the days when heavy-framed barns were built by hand, however, the phrase had another meaning. Builders bored round holes in the gigantic beams of such barns and then, to be sure the buildings were solid and secure for centuries, they drove into those round holes . . . square pegs. A square peg in a round hole was comparable to the hardy soul who refuses to go the easy route and thereby insures the strength of the union. But the original, structural meaning has been lost (so much so that some modern dictionaries offer "a round peg in a square hole" as an interchangeable alternative).

So why is squareness so dominant in American mainstream culture? Like people everywhere on this round earth, we presume that our way of living, our way of seeing things, our way of organizing, is obviously the most logical. Why do we shake hands firmly? Because a firm handshake demonstrates honesty and trust, things like that. Why do we shake hands at all? Because, well, because that shows we're fair and square. There's that word again!



Contrarily, we throw "curve balls"—a double whammy—when we act erratically. "Going in circles" describes wasted time and frustration. If we want to suggest someone is crazy (or in modern parlance, "loopy"), we twirl a forefinger around an ear, as if a madman's problem is that his mind operates in circles. Yessir, he's a *screw*ball! Bad guys are "crooked"; good guys are "straight arrows."

I once asked an Omaha friend about the straight arrow metaphor for virtue; he laughed, saying this is a perfect example of how two peoples can see the same thing differently: "The white man sees only that an arrow goes to its target, not wavering from side to side; we Indians see an arrow's flight in its other dimension, as it rises from the bow and falls to its target."

Has an obsession with straight lines and right angles become a "straight" jacket that restricts our ability to see the world in other terms, to observe through the eyes of those who see the world in circles, arcs, and globes? What happens when we find ourselves in a culture where round is the rule; where, for example, it is not the cross that symbolizes religious understanding but the nested, curved commas that are yin and yang?

The late Lakota holy man Lame Deer, like many Native Americans, lived within a "round" culture and can give us some idea of the cross-cultural experience. He had explicit problems moving within the white man's square and straight world.

1970, at the age of 67, Lame Deer told hnographer-biographer Richard Erdoes:

> o our way of thinking the Indians' symbol the circle, the hoop. . . . The tipi was a ring which people sat in a circle and all the milies in the village were in turn circles ithin a larger circle, part of the larger hoop hich was the seven campfires of the Sioux, presenting one nation. The nation was nly a part of the universe, in itself circular nd made of the earth, which is round, of the ın, which is round, of the stars, which are ound. . . . Our circle is timeless, flowing; it new life emerging from death—life win-ng out over death.
>
> The white man's symbol is the square. quare is his house, his office buildings ith walls that separate people from one anther. Square is the door which keeps rangers out, the dollar bill, the jail. Square e the white man's gadgets—boxes, boxes, oxes and more boxes—TV sets, radios, ashing machines, computers, cars. These l have corners and sharp edges—points in me, white man's time, with appointments, me clocks and rush hours—that's what the orners mean to me.
>
> —*Lame Deer, Seeker of Visions*
> (Simon and Schuster, 1972)

Is it any wonder that the Lakota and maha danced round dances while the pineer favorite was the square dance?

Deploring governmental paternalism, istorian Gilbert Fite recently wrote to .S. *News and World Report* (January 9, 995), "Congress should [abolish] reser-ations and bring [Indians] into the full-ess of American life and society." laybe, instead, we should open our grid-ocked minds and give the mainstream a hance to enjoy the fullness of Native merican life and society. After all, what oes around, comes around.

olklorist Roger L. Welsch lives on a tree arm in Dannebrog, Nebraska.

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Backyard Battle of the Sexes

Among the hedgerows, little brown birds wage gender warfare

by Nicholas B. Davies

"Unobtrusive, quiet and retiring, without being shy, humble and homely in its deportment and habits, sober and unpretending in its dress, while still neat and graceful, the dunnock exhibits a pattern which many of a higher grade might imitate, with advantage to themselves and benefit to others through an improved example." So wrote the Reverend F. O. Morris in *A History of British Birds* (1856), urging his parishioners to emulate the life of the hedge sparrow, or dunnock.

A stroll around an English garden in spring might well lead the casual observer to endorse this view. In Old English, "dun" means dull brown, and "ock" signifies little. The dunnock, not a true sparrow but an accentor, is the archetypal little brown bird and is indeed unobtrusive as it shuffles about under the bushes collecting billfuls of tiny insects for its young. The impression gained might be one of harmonious cooperation, as the dunnocks raise their offspring among a succession of flowers, from the crocuses and daffodils that emerge with the first young of the year in April to the roses that bloom as final broods fledge in July.

Fifteen years ago, British ornithologists Michael Birkhead and Barbara and David Snow began to record the lives of individual dunnocks in detail. The dunnock, they found, belies its dull appearance, having an extraordinarily variable mating system. While one territory might contain a pair—presumably what the Reverend Mr. Morris had in mind for dunnocks—next door a female might be mating with two males or a male with two females. More complex combinations occurred too, with two or three males sharing from two to four females. Had the clergyman's congregation followed suit, the parish would have been in chaos.

In 1981, I began a long-term project to try to discover the causes of this breeding diversity. My study site is the Cambridge University Botanic Garden, a nature reserve within a city and just a short bicycle ride from both home and the university's zoology department. The garden, laid out 150 years ago, provides a mosaic of the various vegetation types favored by dunnocks in more natural habitats throughout Europe, including woodland, hedgerows, and dense scrub. About eighty dunnocks, all color banded for individual recognition, breed in the garden each summer.

The conventional view of pair formation in songbirds is that males first set up territories and advertise for mates by singing. Females are then supposed to choose among male territories, their choices determining male mating success. I spent the first part of each breeding season simply walking around the garden, plotting the positions of individuals on maps, and I soon found that dunnocks did not follow this pattern. Females defended territories against other females, occupying exclusive areas with little overlap between neighbors. They appeared to settle independently of male distribution; rather, their territories were determined by competition with other females for suitable habitat. Males then competed to defend the females, so that the male distribution was superimposed over the mosaic of female territories.

Various mating combinations arose as a result of different patterns of territory overlap. Sometimes a single male defended one female territory (monogamy) or two adjacent females (polygyny). In other cases, two males shared the defense of one female (polyandry) or several adjacent female territories (polygynandry). Males that shared one or more females were not close relatives, and their alliance was an uneasy one. The dominant, or alpha, male (usually the older one) at first tried to evict the subordinate, or beta, male, and only if he was unsuccessful would the two come to share the defense of a joint territory. Some males wandered over the garden for several weeks before they managed to settle as permanent beta males. I occasionally observed intermediate arrangements with, for example, a beta male overlapping two neighboring alpha males. These patterns depended on both male and female territory size. The larger a female's territory, the more difficult it was for a single male to monopolize her, and the larger a male's territory, the more likely he was to have sole or joint defense of two females, especially where female territories were small.

I had to visit the garden daily simply to keep track of these complex systems and the changes that ensued when individuals died and their partners jostled for better mating opportunities. Even I, however, was not prepared for the conflicts that unfolded once breeding began. A visit to a dunnock territory during the mating period has all the drama and excitement of a soap opera. Once she has completed her nest, usually built in a bush or hedge, the female approaches males to solicit copulations. Matings begin three to seven days before the first egg is laid and last right up to the completion of the clutch of three to five eggs, with one egg laid per day in successive days. Monogamous males guarded their females closely and chased off neighboring males that trespassed in search of extra matings. But by far the most intense competition took place where two males shared a territory. Here, the alpha male followed the female wherever she went and attempted to prevent the beta male from copulating with her. Some beta males deferred to the alpha, but others continually approached the female, leading to endless chases in her vicinity.

A female could make life difficult for the guarding alpha male. She often flew ff, with the alpha in hot pursuit, and then uddenly doubled back behind a bush in n apparent attempt to throw him off. She vould then approach the beta male and socit a mating from him. Even when an lpha male was guarding her closely, a fenale sometimes hopped quietly to the far ide of a bush or rock and solicited to the eta before the alpha realized what was appening. Females were intent on preenting alpha males from having excluive mating access.

These exploits were enormously enterining to watch, but the act of copulating self was especially bizarre. It was first escribed by Edmund Selous in 1902: The hen elevated her rump and stood till, when the male, hopping up, made lite excited and very wanton-looking pecks n this region, that is to say into the actual rifice. There was actually no mistaking he nature and significance of the actions, ather lecherousness, as it seemed to me, eing revealed. This is a very remarkable hing. . . but I do not understand it."

This extraordinary cloaca pecking coninues for about a minute before the male opulates. During this time, the other male nay discover him and interrupt, which nade me wonder why the first male did ot copulate straightaway to insure that his perm entered the female. When I looked nore closely, I noticed that during the ecking, the female's cloaca made pumpng movements, and she sometimes jected a small droplet. This is certainly vhat the male is waiting for, because as oon as it is produced, he looks at it briefly nd then copulates.

I can still remember my excitement vhen I first noticed a droplet being jected. I immediately got on my hands nd knees and began to search for it. Even vhen I had watched the displays at close ange, this was a difficult job, and I manged to discover only three in the first year.

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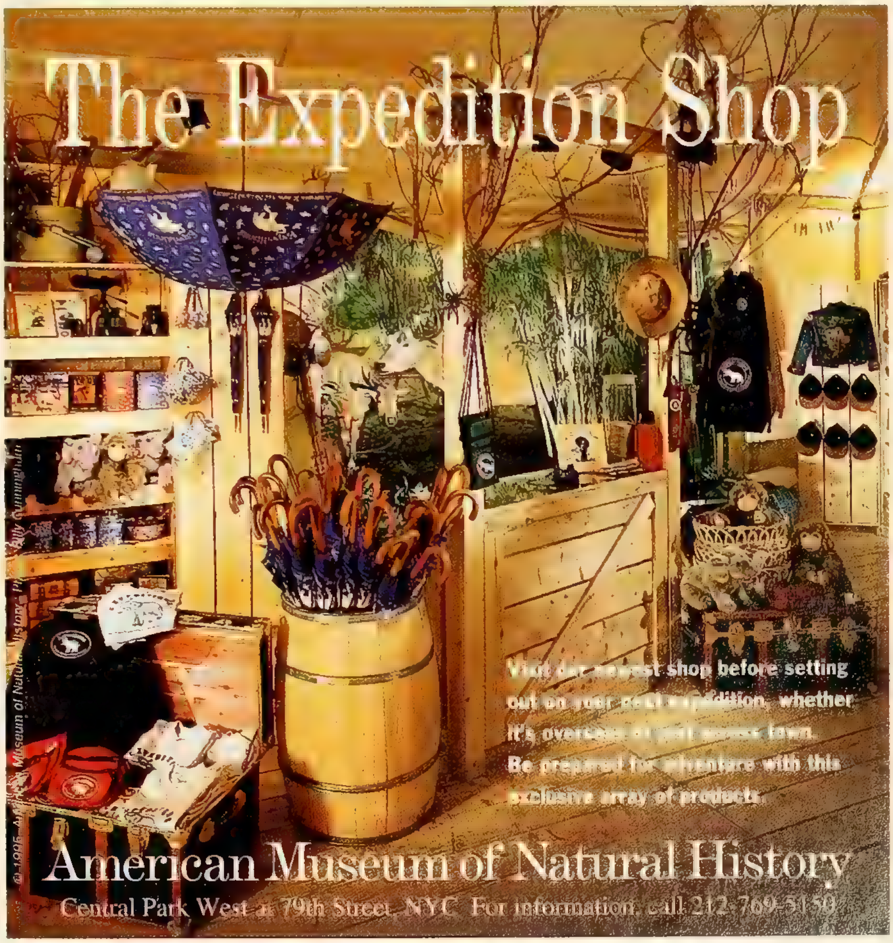
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I rushed back to the laboratory and was thrilled to see, through a microscope, that the droplets contained masses of sperm.

Like other birds, female dunnocks store sperm. They have some 1,400 little tubes at the junction of the uterus and vagina. In contrast to many monogamous species, whose females copulate from one to twenty times per breeding attempt, in dunnocks copulation is frequent as the males battle for paternity. Females with two males may copulate up to six times per hour; possibly several hundred times per clutch. As a result, there will be a pool of sperm in the female's cloaca and vagina for much of the mating period. The male's pecking stimulates the female to eject the pool to make way for his insemination and so give his own sperm a better chance of reaching the storage tubules.

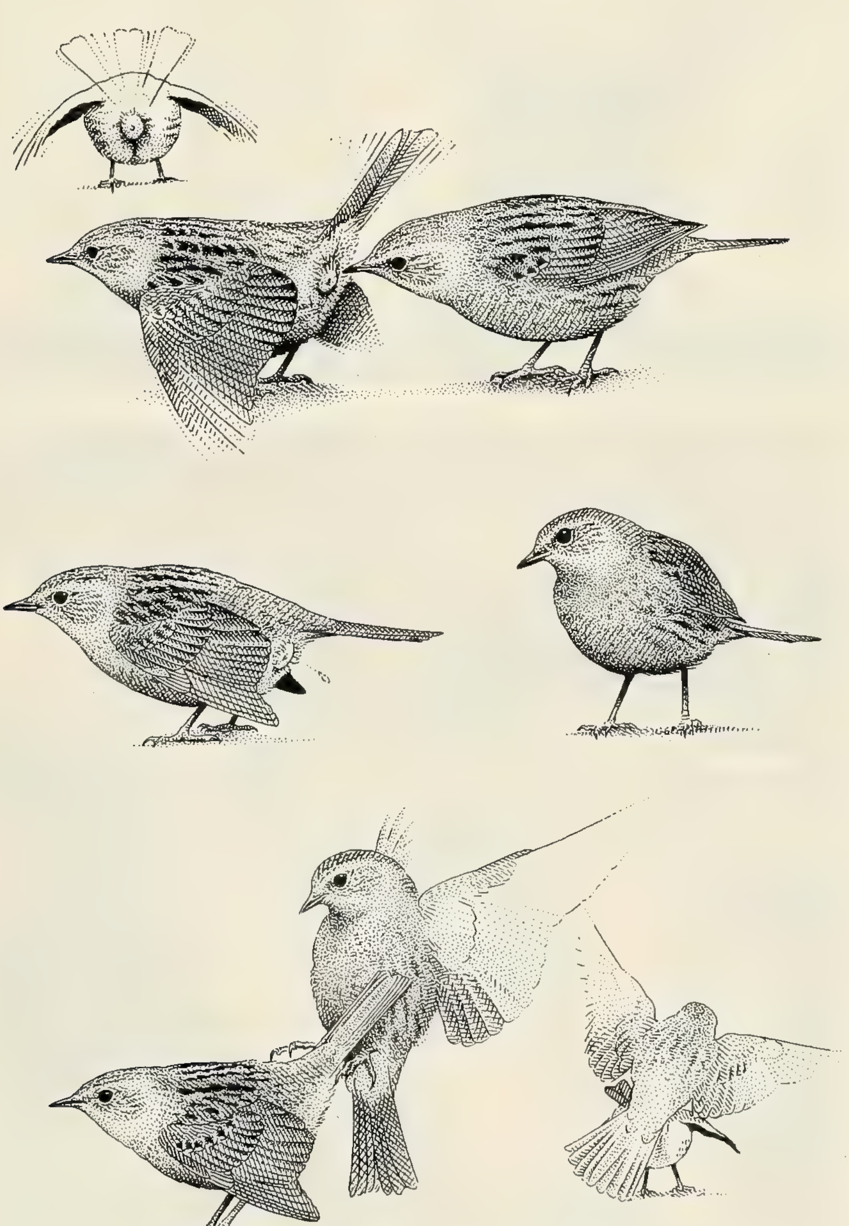
After the excitement of the mating period, life on a dunnock territory becomes peaceful during incubation. It is as if a whistle had been blown to signal the end of a game. Females alone incubate the clutch for eleven to twelve days, and then males help them with chick feeding for eleven to twelve days in the nest and another two weeks after fledging, until the young become independent.

One of the problems of working in a public garden is that people often come up and ask what you are doing. When I am crawling about looking for sperm droplets, a truthful reply entails a rather detailed explanation to be convincing and so I usually announce that I am "weeding." My most memorable encounter was with a nun. I was banding a brood of nestlings when she approached and asked what was so interesting about dunnocks. In this case, I felt obliged to tell the truth and described how two males competed for matings. "And which male fathers the chicks?" she asked. I had to admit that I did not know. "Well surely that should be easy to discover," she replied. "Why don't you try DNA fingerprinting?"

The year was 1987, and the nun, a teacher at a school nearby, had read of this newly developed method for accurately determining maternity and paternity using variations in DNA as markers. My colleague Ben Hatchwell and I took the good lady's advice and spent the next three summers collecting blood samples from all the adults and their offspring. Terry Burke, Mike Bruford, and Tim Robson, of Leicester University, then analyzed the samples. The results showed that all the young belonged to the female attending the nest. In monogamous and polygynous arrangements, the single male defending the territory fathered all the young. Where two males defended a territory, the alpha male fathered all the young in most of the cases where our observations had shown that he successfully monopolized the female at mating time. However, where the two males had shared matings, paternity was often mixed; on average the alpha fathered 55 percent of the brood and the beta 45 percent.

These data made very good sense of when and how often males fed chicks. When only the alpha male had gained matings with the female, only he helped her feed the brood. However, if the males had shared matings, both helped. I saw no evidence that a male could recognize his own young. If a male had mated with a female, he helped to feed her young, even in cases where, by chance, the other male had fathered the whole brood. Furthermore, when the chicks fledged, they were often divided among the parents, with each adult taking sole charge of one or two young and feeding them for the further two weeks to independence. In such brood division, males showed no tendency to pick out their own young for care.

Males clearly behaved selfishly, using their mating success as an indirect cue to paternity and helping to feed the young



From top to bottom: A female dunnock solicits copulation from a male. He pecks at her cloacal opening and then stands by until the female ejects a droplet containing the sperm of previous suitors. The pair then proceed to copulate.

Drawings by David Quinn, from *Dunnock Behaviour and Social Evolution,* by N. B. Davies (Oxford University Press, 1992)

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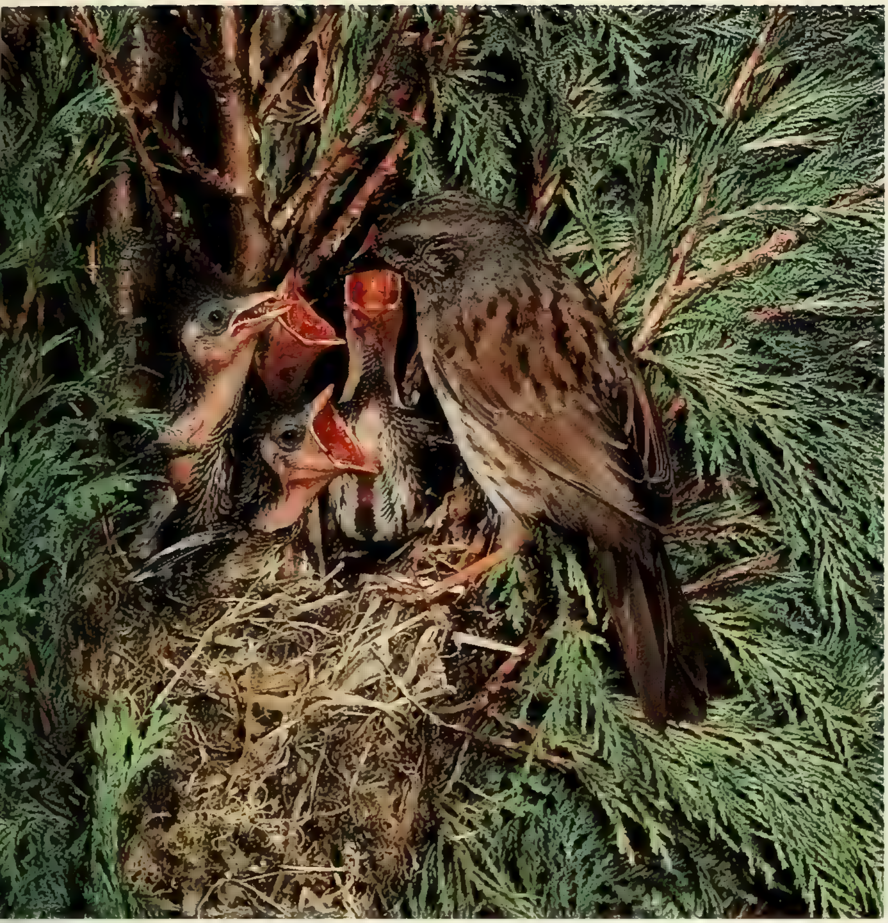
only when they had had a chance of fathering some of the brood. The DNA fingerprinting showed that mating share gave a good indication of paternity share and also that the two males varied their share of work during the chick-feeding stage in proportion to their share of matings. For example, beta males that gained a greater share of the copulations fed chicks more often. Ben Hatchwell and I were able to manipulate relative parental effort by varying the males' share of matings experimentally. We removed alpha males at various stages of the females' breeding cycle and kept them in aviaries for three days. Then we put them back in their territories. Males removed after the eggs had been laid, when the matings had finished, fed the chicks normally. However, when we removed an alpha male during the mating period, and so allowed the beta male to gain most of the matings, the beta male now worked harder at chick feeding than the alpha. This experiment shows that males varied their parental effort in relation to their chances of paternity, not simply to dominance rank.

We were now able to calculate an individual's reproductive success (number of young produced) in the different mating combinations. The results made beautiful sense of the conflicts seen at mating time. From the female's point of view, success during the mating season was simply the number of healthy young raised on her territory. This depended on the amount of help she got from males in caring for chicks. For a female, polygyny was the least successful strategy because she had to share the help of one male with another female, and her chicks often starved to death. In polygynous situations, females were often aggressive to each other, engaging in chases and fights. If one of them could drive the other away or force her to desert her nest, the aggressor might thereby claim the male's full-time help and so enjoy the greater success of monogamy. A polyandrous female was even more successful because two males helped at the nest. This explained why females encouraged beta males to copulate with them. They could thus insure their future help in caring for young.

In contrast, a male fares least well in polyandry; although more young are raised with the help of three providers, some of the young are not his. Hence monogamy is more profitable for a male: the pair-fed brood is smaller, but all the offspring are his own. This explains why alpha males act against the female's



A parent dunnock brings a billful of small insects to its seven-day-old chicks. The nest, in the dense cover of a cypress, is constructed of twigs, grass stalks, leaves, and moss and lined with hair or feathers.

Stephen Dalton; NHPA

wishes and try to drive beta males away or at least prevent them from copulating. A male does best of all in polygyny, the system in which a female does worst. Although each female is less productive, the combined output of two females in polygyny exceeds that of one female in monogamy.

The dunnocks' variable mating system thus reflects a battle between the sexes. Where a female wins out over the conflicting interest of the alpha male, we see polyandry, with two males sharing matings and parental care. Where a male wins, despite the conflicting interests with his females, we observe polygyny. Monogamy occurs when neither sex can gain a second mate. Polygynandry—for example, two males with two females—can be viewed as a "stalemate"; the alpha male is unable to drive the beta male off and so claim both females for himself, and neither female is able to evict the other and so claim both males for herself.

The Reverend Mr. Morris's charming description of the dunnock was published three years before the appearance of Darwin's *On the Origin of Species*. Ten years later, Morris still rejected Darwin's ideas, so he would not have agreed with my evolutionary interpretations of dunnock behavior. But at least he might have been amused to see that conflicts of interest and imperfections, which no doubt occurred among his parishioners, also dominated the lives of these little brown birds.

Recent studies of other species, combining observations of behavior with genetic analysis of parenthood, show that the dunnock may not be unusual. Even in cases where small birds are apparently cooperating in simple pairs, extra-pair matings are often rife. A closer look promises to reveal many surprises, perhaps even in the species breeding in our backyards.

Nicholas B. Davies teaches behavior and ecology in the Department of Zoology at Cambridge University, where he is a Fellow of Pembroke College. He is the author of Dunnock Behaviour and Social Evolution *(Oxford University Press, 1992).*

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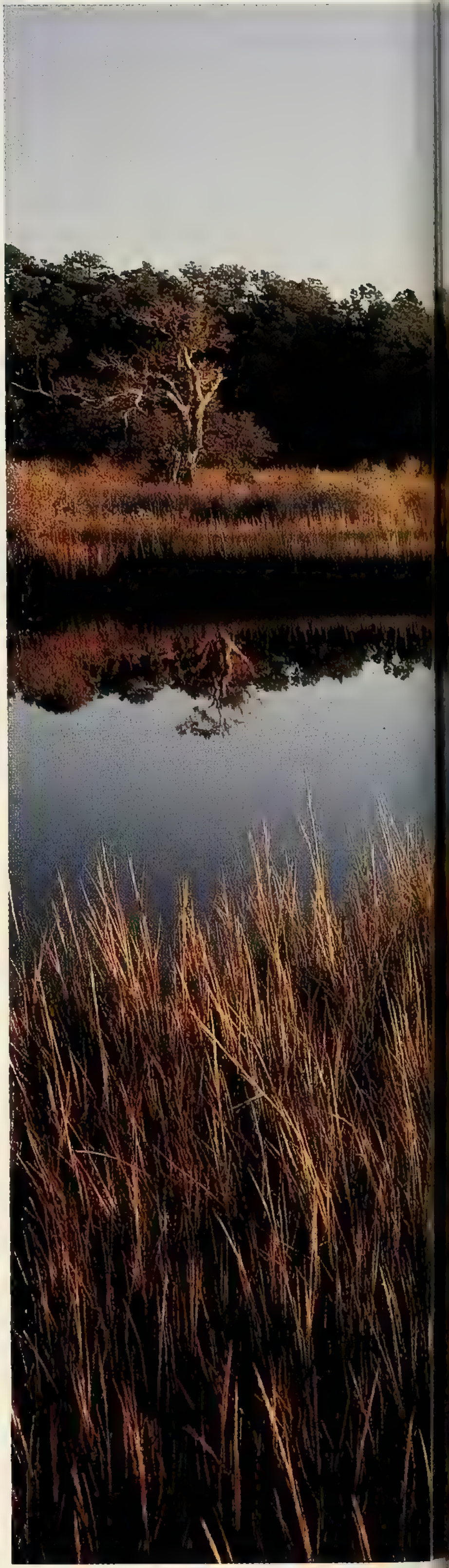
Cedar Point, North Carolina

by Robert H. Mohlenbrock

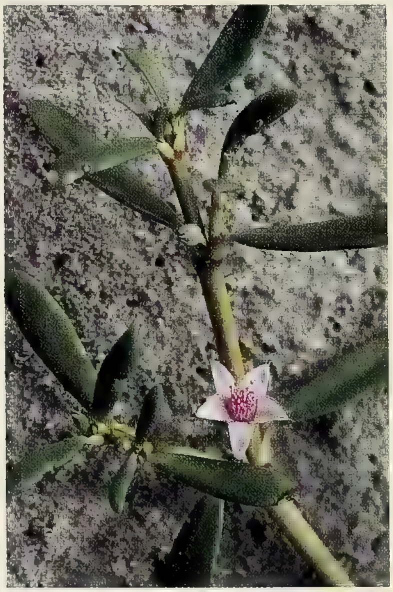


At less than 250 square miles, Croatan is one of the smallest U. S. national forests, but it contains many biological attractions. It is the northernmost national forest where the American alligator and the Atlantic white cedar have been recorded. It is home to copperheads, cottonmouths, and three kinds of rattlesnakes. And its pocosins, or hillside swamps, harbor eleven different kinds of carnivorous plants (*see* "This Land," *Natural History,* June 1985). Located on the coast of North Carolina between New Bern and Swansboro, Croatan also embraces Cedar Point, where plants and animals thrive in the salt water of a tidal estuary.

At Cedar Point, sea water from the Atlantic Ocean meets and mixes with fresh water from the White Oak River, whose lower reaches are a mile wide. The gentle, sandy ridges and dry woods of Cedar Point are broken up by lower areas of moist woods and brackish marsh that adjoin inlets of the estuary. The U. S. Forest Service has constructed an interpretive trail that meanders through this varied habitat. It is one of about 800 National Recreation Trails designated by the Federal government.

From a parking lot, the trail leads through a woods where loblolly pines, water oaks, and sweet bay magnolias grow among shrubs of bayberries, high-bush blueberries, yaupon hollies, and Hercules'-clubs. Other plants in this heavily disturbed area include giant cane (a type of bamboo), round-leaved greenbrier, muscadine grape, and poison ivy.

As the trail drops imperceptibly toward the White Oak River, a marsh comes into view. A boardwalk through it permits close inspection of the vegetation. Among the species adapted to the brackish water are salt marsh cordgrass; a much larger, dark brown to blackish cordgrass known as needlerush; seaside goldenrod; and the shrubby salt marsh elder, a greenish flowered plant related to giant ragweed. Growing with these are two kinds of plants that do equally well in freshwater areas—switch grass, a large, clump-forming grass that may grow six feet high, and southern red cedar, a small to medium-sized tree that probably gives Cedar Point its name. Southern red cedar is related to the more common eastern red cedar, which is also present, but not in the brackish areas.

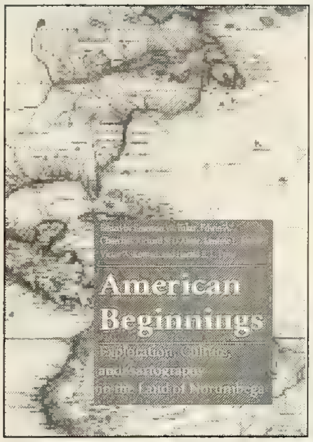


Sea purslane survives on ground that is subject to the fluctuating tide.

Jessie M. Harris

The trail advances into a sandy upland woods supporting red bays, wax myrtles, loblolly pines, water oaks, and scraggly

Salt marsh cordgrass thrives along the estuary of the White Oak River.
David Muench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Exploration, Culture, and Cartography in the Land of Norumbega

American Beginnings
Exploration, Culture, & Cartography
in the Land of Norumbega

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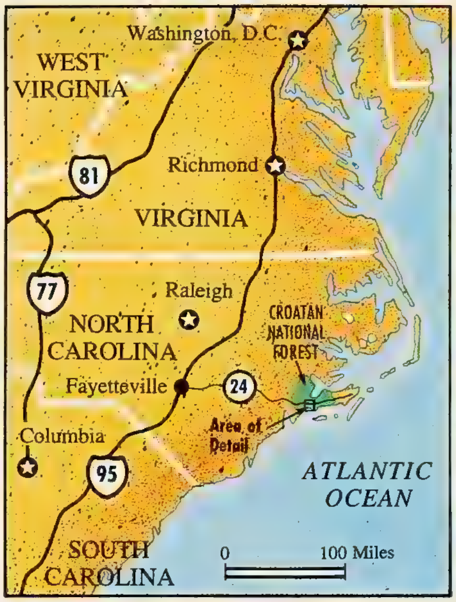
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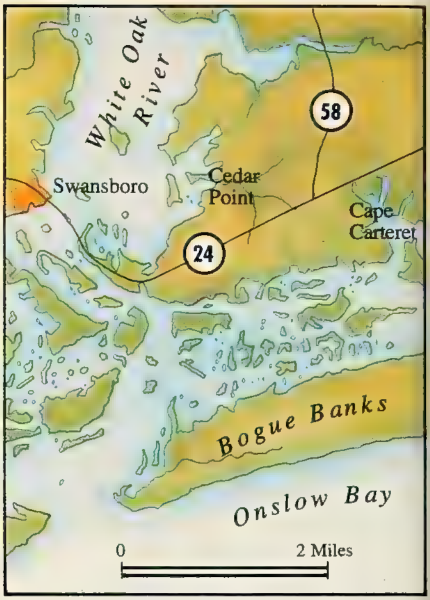
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Swansboro
Cedar Point
Cape Carteret
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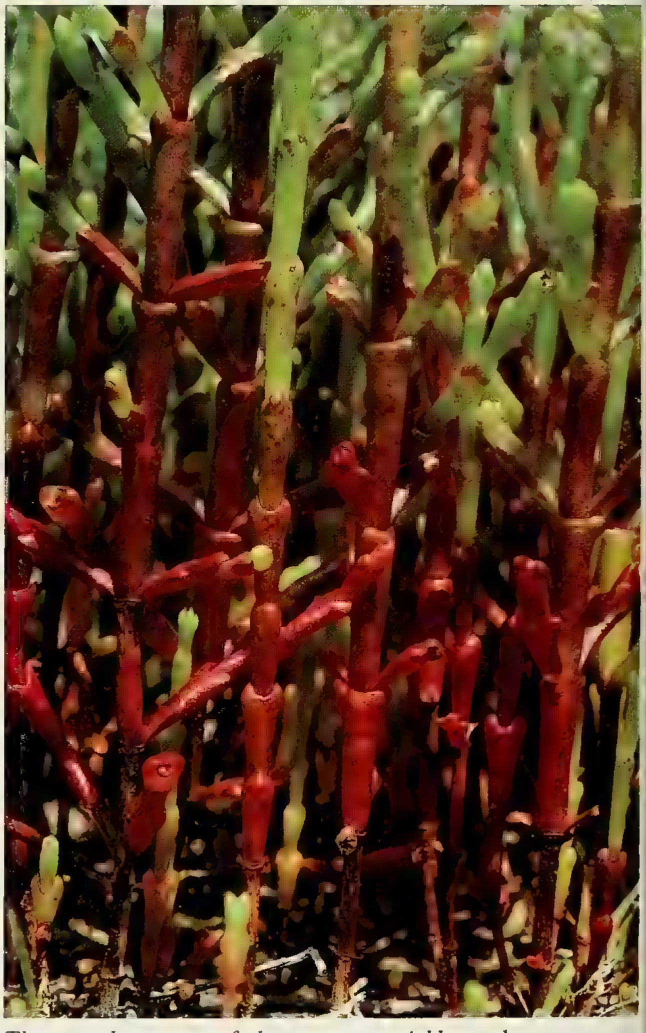
Bogue Banks
Onslow Bay
0
2 Miles

Joe LeMonnier

leather-leaved oaks above a grassy understory of little sea oats, hairy panicum, and melic grass. The influence of the salt water is evident in the encroachment of needlerush and seaside goldenrod.

Another boardwalk takes the hiker into a large, brackish marsh where open water and little streams surround clumps of salt marsh cordgrass and needlerush. Several dead snags stand in the marsh, the remains of pines that could not tolerate the salt water. Some of the birds that frequent the marsh are the great blue heron, snowy egret, kingfisher, semipalmated plover, osprey, willet, and black duck.

Here the ebbing tide exposes patches of soil where fiddler crabs come out to feed. The male fiddler crab is the one with the large claw, which it waves to attract the attention of the female. Plants tolerant of salt water also inhabit these patches of ground and survive through the fluctuations of the tide. They include sea oxeye, which has small sunflowerlike heads; a couple of short, narrow-leaved, wiry grasses known as salt grass and salt marsh dropseed; a perfectly branched, nearly leafless plant with papery flowers called sea lavender; and sea



The succulent stems of glassworts, or pickleweeds, turn red in the fall.

C. C. Lockwood; Bruce Coleman, Inc.

Cedar Point

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ourslane and glasswort, which are both succulents.

Sea purslane has flat, fleshy leaves and ive-petaled, purplish flowers. Glassworts, also called pickleweeds, have upright, succulent, jointed stems without leaves. Their flowers usually form in groups of hree in the hollow of the uppermost oints. In late summer, the stems turn red.

After leaving this part of the marsh, the rail meanders in and out of a diverse up-and forest that contains black gum, tulip oplar, American holly, water oak, oblolly pine, white oak, chestnut oak, wild black cherry, and sassafras. The trail swings back near the marsh one more ime, then enters moist woods dissected by a small stream. These woods are home to sweet gum, southern magnolia, red maple, white alder, and witch hazel. Along the stream are such wetland species as button-ush, poison sumac, and cinnamon fern.

Biologists estimate that approximately 5 percent of all ocean life originates in, or s dependent on, estuaries, which are ex-remely high in nutrients. Biologists con-sider tide-washed brackish marshes, such as that at Cedar Point, to be more produc-ive than the richest farmlands. One source of nutrients are the microscopic organisms nown as plankton, which stream into the estuary with high tide, providing food for ish and shellfish. In addition, as larger plants and animals that live in the marsh die, their detritus, or decaying organic matter, is broken down into nutrients by bacteria, fungi, and algae, which in turn are the major source of food for snails and crabs. Ultimately, the fish, snails, and crabs are eaten by shorebirds and mam-mals such as raccoons, opossums, and of course, humans.

Robert H. Mohlenbrock, professor emeri-us of plant biology at Southern Illinois University, Carbondale, explores the bio-ogical and geological highlights of the U. S. national forests and other parklands.

The humpback of Notre Dame.

The migratory path of the humpback whale passes through the rich waters of Notre Dame Bay, Newfoundland.

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by Joe Rao

On the morning of the 15th, the moon will undergo a partial eclipse. But only those who live west of a line extending from northwest Minnesota to central Louisiana will be able to see any part of this event; for those east of this line, the moon will set before the eclipse gets under way. The best view will be along the West Coast and in Hawaii, where the eclipse will be visible in its entirety in the early dawn. The moon will enter the earth's shadow at 4:41 A.M., PDT. Maximum eclipse comes at 5:18 A.M., PDT, when the upper 12 percent of the moon's disk is within the umbra. The eclipse ends at 5:55 A.M., PDT. Just before the eclipse gets under way, the moon occults the bright star Spica—a sight that will be visible in almost all of North America.

Two weeks later, at new moon, an annular (ring) eclipse of the sun will take place. The path of annularity begins in the South Pacific and passes through northern Peru, southern Ecuador, southern Colombia, and northern Brazil before ending in the Atlantic. In the United States, only those on the Florida peninsula can (with proper eye protection) witness a slight incursion of the moon's disk in front of the sun's lower-left edge in the early afternoon. In Miami the eclipse begins at 1:14 P.M., EDT, reaches a peak of 12 percent at 2:10 P.M., EDT, and ends at 2:59 P.M., EDT.

THE PLANETS IN APRIL

Mercury reaches superior conjunction on the 14th and perihelion on the 23d as it moves rapidly east of the sun into the early evening sky. Indeed, it should be easy to spot the planet by the 23d. Look very low in the west–northwest, to the lower right of Aldebaran. On the 30th, Mercury hovers well above an exceedingly thin crescent moon, only about thirty-three hours past new phase. The planet will be just 3 degrees south of the Pleiades star cluster, which sets as twilight ends.

Venus lingers low in the eastern predawn sky. It rises about an hour before sunrise by month's end but is still the brightest object in the sky except for the moon. Venus passes within a degree of much fainter Saturn on the morning of the 13th. On the mornings of the 26th and 27th, watch the waning crescent moon pass well to the north and east of Venus.

Mars continues to fade as it recedes from Earth, but the red planet is still conspicuous, partly due to its extreme brightness at the start of the month and partly because of its position in a relatively star-poor region of the sky (between the faint constellation of Cancer and the sickle of Leo). Now high in the south–southeast at dusk, Mars remains visible in the sky until at least 2:45 A.M., local daylight time. Traveling eastward among the stars, Mars moves closer and closer to Leo's sickle by the end of the month.

Jupiter begins its retrograde motion among the stars, rising within five hours of sunset on the 1st and about half an hour after the end of evening twilight on the 30th. The waning gibbous moon passes north of this brilliant beacon on April 17–18.

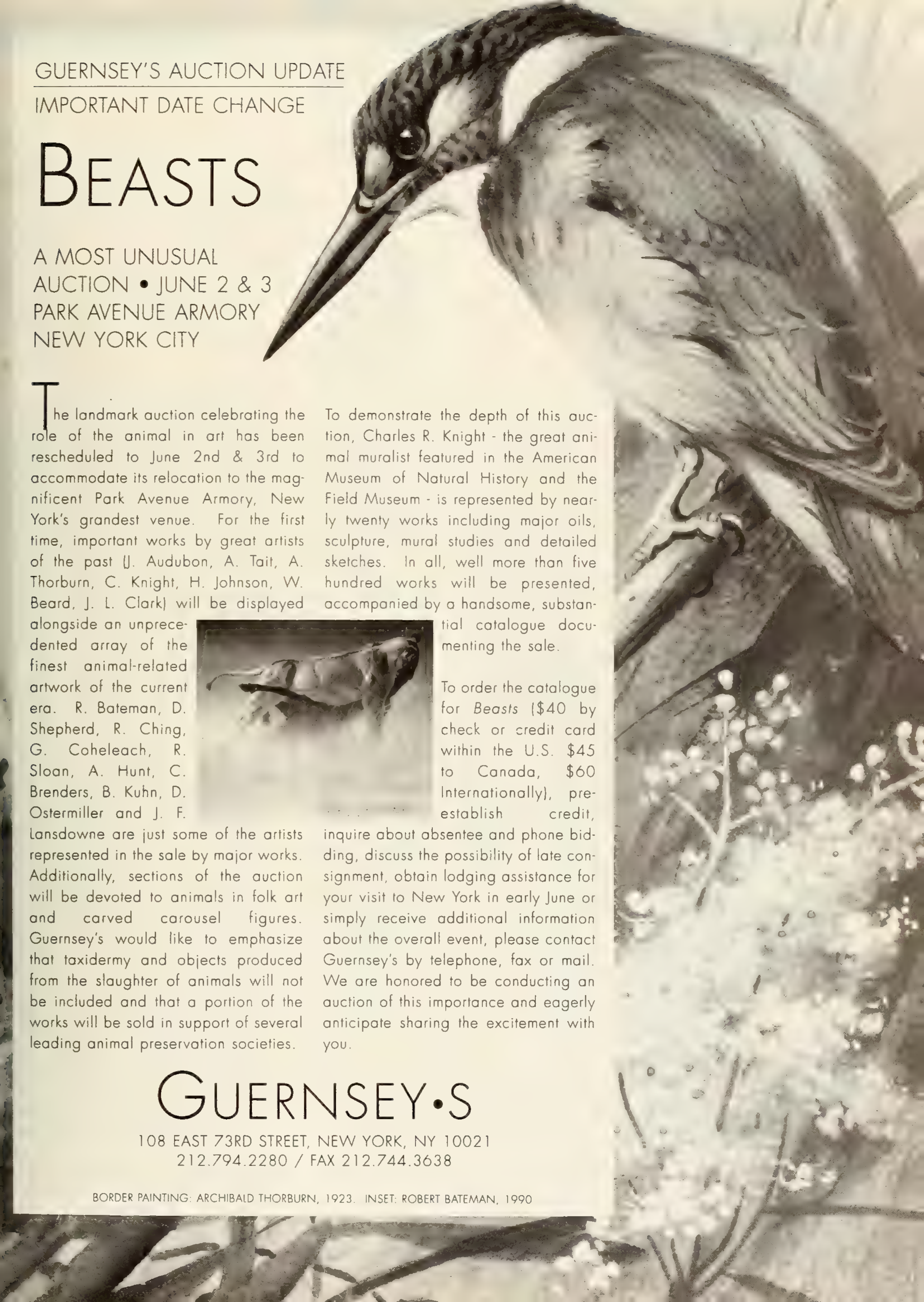
Saturn moves slowly out of the bright morning twilight during the first half of April, finally becoming favorably placed for viewing, low in the southeast before sunrise. Saturn is the much fainter first-magnitude object immediately below brilliant Venus on the morning of the 13th. On the 25th, you'll find Saturn well below and slightly to the left of the waning crescent moon.

The **Moon** reaches first-quarter phase on April 8 at 1:35 A.M., EDT; full moon is on the 15th at 8:08 A.M., EDT; last quarter occurs on the 21st at 11:18 P.M., EDT; and new moon is on the 29th at 1:36 P.M., EDT.

The **Lyrid** meteor shower begins after the 16th and peaks on the night of the 21st and the early morning of the 22d, when it averages one "shooting star" every five minutes. These meteors, which appear to radiate from the brilliant blue-white star Vega, continue intermittently until about the 25th. The moon is at last quarter on the 21st, so it should not interfere with viewing until shortly before dawn.

Daylight saving time begins on the first Sunday of April at 2:00 A.M. So set your clocks ahead one hour before going to sleep.

Joe Rao is a meteorologist and a guest lecturer at the American Museum–Hayden Planetarium.



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To demonstrate the depth of this auction, Charles R. Knight - the great animal muralist featured in the American Museum of Natural History and the Field Museum - is represented by nearly twenty works including major oils, sculpture, mural studies and detailed sketches. In all, well more than five hundred works will be presented, accompanied by a handsome, substantial catalogue documenting the sale.

To order the catalogue for *Beasts* ($40 by check or credit card within the U.S. $45 to Canada, $60 Internationally), preestablish credit, inquire about absentee and phone bidding, discuss the possibility of late consignment, obtain lodging assistance for your visit to New York in early June or simply receive additional information about the overall event, please contact Guernsey's by telephone, fax or mail. We are honored to be conducting an auction of this importance and eagerly anticipate sharing the excitement with you.

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Of Conjurers and Kings

by Bob Brier

Magic and religion were inseparable in ancient Egypt, as Geraldine Pinch elucidates in her book, *Magic in Ancient Egypt*. Nineteenth- and early-twentieth-century scholars and anthropologists made distinctions between magic and religion, one scholar saying, "Magic, after all, is only the disreputable basement in the house of religion." Pinch, an Egyptologist at Cambridge University, is intrigued by the inseparability of the two realms. "The theory," she says, "that magic is always unorthodox and subversive, part of a religious and political counterculture, does not seem to apply in Egypt where ritual magic was practised on behalf of the state for at least three thousand years." Although lay magicians unattached to an institution existed in ancient Egypt, by far the most numerous were the trained priest-magicians from established temples, who were part of the orthodox hierarchy and whose job was primarily to be a stand-in for the pharaoh. Today we expect our clergy to have entered into their profession because of a deep religious commitment. In ancient Egypt, however, being a priest was merely a job, a means of making a good living and having status in the community.

The rituals of the priest-magician still persist in Egypt, as I was to discover while doing research in Luxor about a dozen years ago. My stay coincided with the Festival of Abul Haggag, commemorating a nineteenth-century Muslim holy man buried among the 3,000-year-old carvings of Egyptian deities inside the temple of Luxor. On the fourteenth day of the Islamic month of Shabân, a twelve-foot boat is taken from its place in front of the Abul Haggag Mosque and, accompanied by an exuberant crowd, rolled on wheels through the streets of Luxor, northward to the temple of Karnak, two miles away. The assemblage, reminding me of college students following a parade float, makes stops at the burial places of local saints along the route. They recite verses from the Koran before eventually returning to the temple of Luxor.

Later I asked a well-known Luxor elder and antiquities dealer about the significance of the boat. He said that the answer was written in the carvings of the temples at Luxor and Karnak. So I took a closer look at the temple walls depicting the Festival of Opet, a yearly celebration when Luxor was the capital of Egypt during the New Kingdom (1550–1070 B.C.). For the festival, the statues of the god Amon, his consort Mut, and their son, Khons, were taken from their shrines at Karnak, placed in model boats, which were carried onto barges decorated with gold and silver, and towed down the Nile to Luxor.

MAGIC IN ANCIENT EGYPT, by Geraldine Pinch, *University of Texas Press, $18.95; 191 pp., illus.*

Statues of the gods had tremendous oracular powers for forecasting the future and dispensing divine guidance. An Egyptian papyrus, now in the British Museum, recounts how the statue of Amon solved a theft during the Festival of Opet. A local citizen named Amunemwia (the name means "Amon in the sacred boat") had five shirts stolen from a storehouse he was guarding. During the festival, as the priests paraded the statues in their boat shrines, the populace was permitted to approach and ask questions or dispensations

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f these oracles. Amunemwia asked, “My ood and beloved lord, wilt thou give me ack their theft?” According to the pa- yrus, the god “nodded very greatly.” Possibly the priests dipped the shrine they ere holding?) Then Amunemwia began eading a list of suspects. When the name f a farmer was read, the statue nodded gain. The culprit confessed and eventu- lly returned the shirts. The statues were nen transported back to Karnak in a pro- ession that represented the ceremonial estoration of world order. Thus, in Abul laggag’s festival, I had witnessed the an- ient ritual magic associated with the Fes- val of Opet incorporated into a Muslim eligious celebration.

In *Magic in Ancient Egypt,* Pinch visely avoids overanalyzing and lets the ractices speak for themselves. The reader s presented with the vast array of ancient nagical procedures for every occasion, mployed by ancient Egyptians from the op down. Since the gods dominated all spects of ancient Egyptian life, the pan- neon included the god of magic, Heka. But every deity and lesser supernatural eing also had access to magical powers, alled *heka*. A priest performed magical eremonies as often as religious ones. (Pinch points out that because women vere mostly illiterate, very little is known bout priestesses’ participation in ritual nagic.) Perhaps the only real distinction or ancient Egyptians was that magical rit- als were usually called upon for individ- al crises, while religious rituals were in- ended to benefit the common good.

The book is more compilation than nalysis, but I was happy to have it all in one place for reference. In her chapter, “Written Magic,” Pinch elucidates the power of the written word. In magical

The author of *The Selfish Gene*

Richard Dawkins explains the replication bomb called “life.”

Photo by Lisa Lloyd

What is the purpose of life? In *River Out of Eden* Richard Dawkins explains how evolutionary biology provides the answer: Life exists to create more life. All living things are mere vehicles of information, gene carriers whose primary purpose is propagation of their own DNA. Hailed by the *New York Times* for “the sort of science writing that makes the reader feel like a genius,” Dawkins answers tantalizing questions:

- Why do we inherit genes for fatal illnesses?
- Why is the sex ratio fifty-fifty in most species when relatively few males are needed to impregnate many females?
- How does Darwinian theory explain the origins of intricate organs like eyes?
- Why are forest trees tall—wouldn’t each survive more economically if all were short?
- Why is our most recent universal ancestor more likely to have been an Adam than an Eve?

River Out of Eden

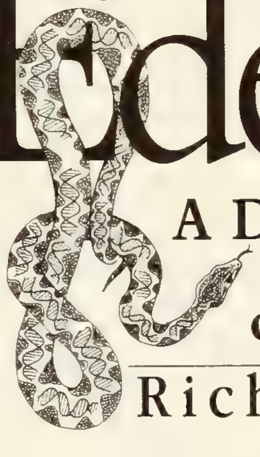
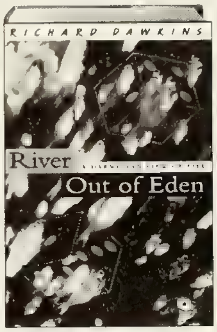


Illustration by Lalla Ward

A Darwinian View of Life



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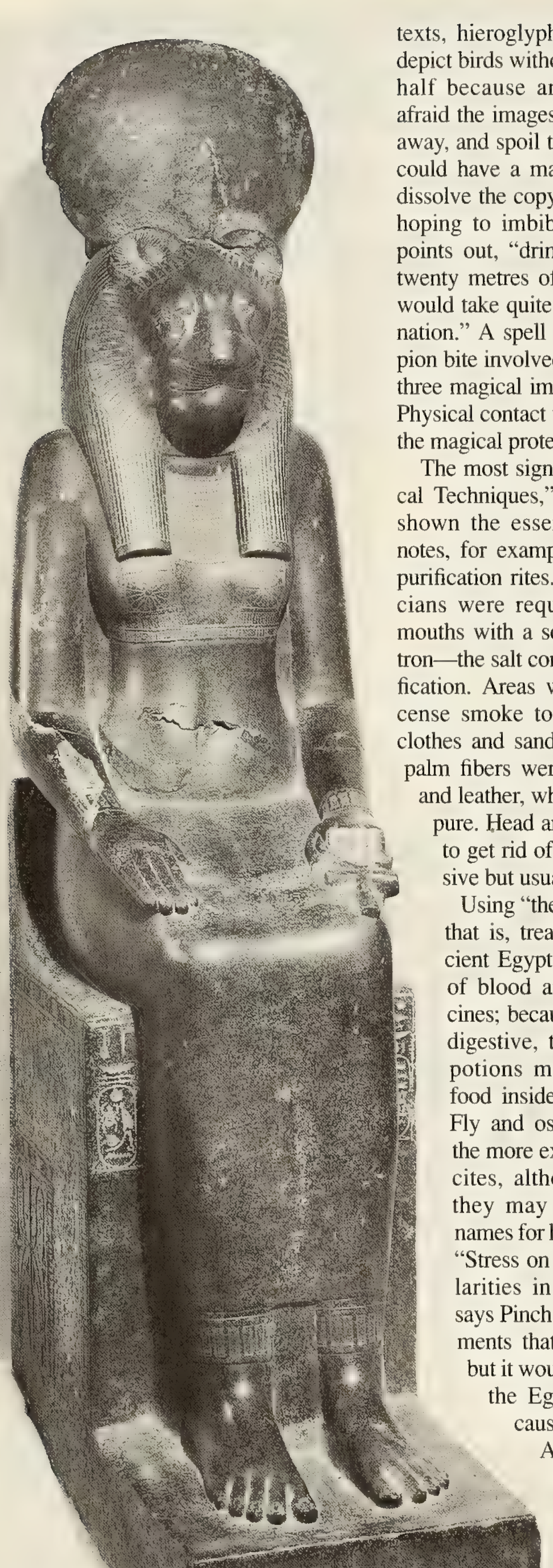


Sekhmet, goddess associated with plague
Courtesy of the Trustees of the British Museum

texts, hieroglyphic images occasionally depict birds without feet and snakes cut in half because ancient Egyptians were afraid the images might come to life, run away, and spoil the spell. Wealthy people could have a magical spell copied, then dissolve the copy in beer and drink it up, hoping to imbibe the magic. As Pinch points out, "drinking your way through twenty metres of *The Book of the Dead* would take quite some time and determination." A spell to cure a snake or scorpion bite involved the patient's licking off three magical images drawn on his hand. Physical contact with the words enhanced the magical protection.

The most significant chapter is "Magical Techniques," in which the reader is shown the essentials of rituals. Pinch notes, for example, the use of elaborate purification rites. Officiating priest-magicians were required to rinse out their mouths with a solution of water and natron—the salt compound used in mummification. Areas were fumigated with incense smoke to kill insects, and linen clothes and sandals made from reeds or palm fibers were worn instead of wool and leather, which were considered impure. Head and body hair was shaved to get rid of lice. The list was extensive but usually practical.

Using "the principle of similars"—that is, treating like with like—ancient Egyptians made extensive use of blood and excrement as medicines; because many problems were digestive, they reasoned that such potions might enable putrefying food inside the body to come out. Fly and ostrich dung were among the more exotic remedies that Pinch cites, although she suggests that they may be merely descriptive names for herbs or other substances. "Stress on the significance of similarities in name or appearance," says Pinch, "sometimes led to treatments that were actually harmful, but it would not have been easy for the Egyptians to pinpoint the cause of failure."

Amulets, small objects the ancient Egyptians wore for protection, still exist by the millions. Often they were small figures of the gods similar to Catholics' Saint Christopher medals, but many had no immediate association with deities: two fingers (used in funerary rites to bring speech and breath to a mummified body), papyrus columns (for stability and strength), and lotus flowers (for rebirth). The color of an amulet was more important than the substance from which it was made. A spell might require that an amulet be made of the red carnelian stone; however, it was the very powerful color red (representing the blood, magic, and power of the goddess Isis) that gave the amulet its value, not the stone. The famous gold mask of Tutankhamen, for example, was inlaid with paste imitating lapis lazuli, again because the power of the mask resided in the color blue—probably associated with the sky and resurrection.

One of the most common amulets was the scarab, which remained a powerful image for thousands of years. Unfortunately, Pinch does not include one of my favorite scarab spells (elaborated in the Leiden-London magical papyrus) designed to make a woman fall in love with a man. The instructions are too complex to include in full (which may explain why Pinch leaves it out) but involve reciting incantations over many days; cutting the scarab in half and taking its right half and the nail parings of the practitioner's right hand and foot and cooking them in a new pot with vine wood; then repeating the spell seven times while making the woman drink the wine:

> Take away her sleep by night; give her lamentation and anxiety by day; let her not eat, let her not drink, let her not sleep, let her not sit under the shade of her house until she follow [?] him to every place in which he is.

In the final act in this drama, the other half of the scarab, with nail parings from the practitioner's left hand and foot, is tied in a strip of linen along with myrrh and saffron around the man's arm while he sleeps with the woman. With such intensive persuasions—not to say brainwashing—what woman could resist the spell?

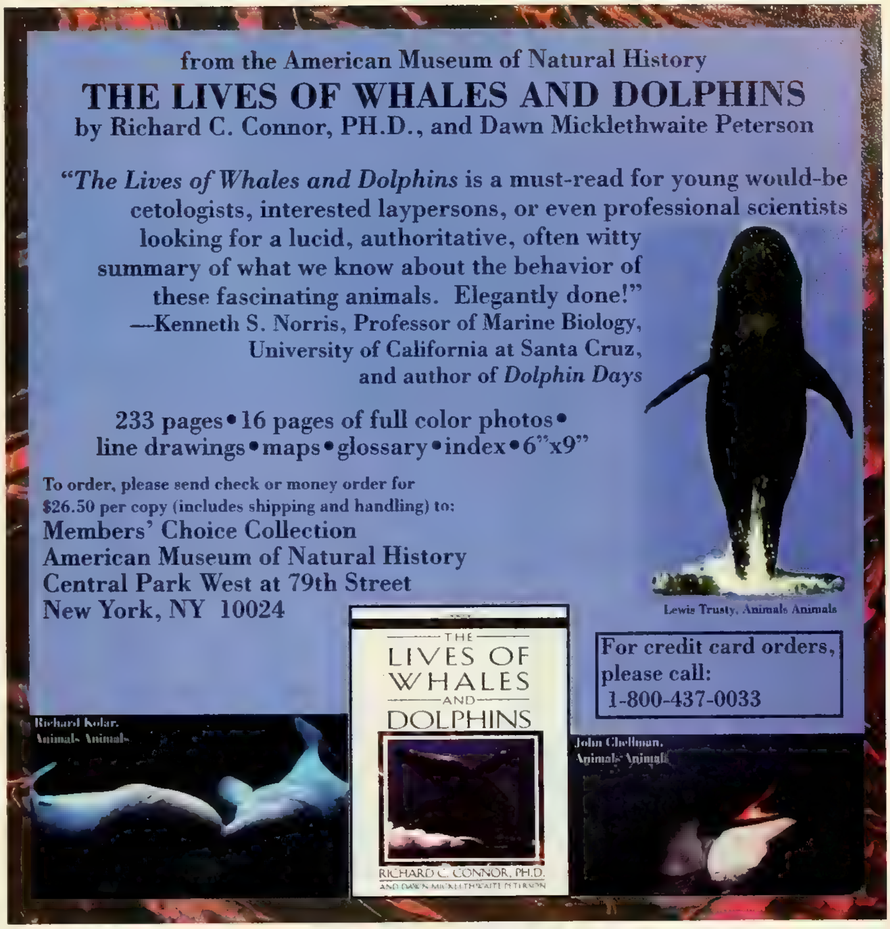
One of Pinch's most interesting chapters is "Medicine and Magic." Most of the medical papyri include magical spells, an exception being the fascinating Edwin Smith Surgical Papyrus (written circa 1600 B.C., with some parts that probably date back to the third millennium B.C.). The nearly purely clinical text describes a series of injuries from the head downward and tells physician how to examine and treat them. Because the injuries involved trauma, and the causes of the problems were known, the treatment was straightrward and governed by systematic sci-tific principles. In one instance, the ysician was even instructed how to obe the brain and remove cranial splin-rs.

But when the cause of an illness was known—what we would recognize day as those diseases caused by mi-oorganisms such as bacteria or ruses—ancient Egyptians mobilized agical spells, rituals, and potions to treat e mysterious infections. Often, espe-ally in funerary rites, they assigned a ity to various parts of the body to protect e healthy or to prevent an illness from reading. One spell in *Papyrus Leiden I 8* names the particular gods responsible r the specific parts of the patient's body: e solar eye of Ra-Atum, the creator, otects the patient's right eye; the lunar e of Horus, representing the force of der, protects the left; the earth god, Geb, ersees the back; the sky goddess, Nut, e belly; their children Isis and Nepththys atch over the thighs; the baboon god, aba, guards the penis; and Shu, associ-ed with powers of renewal, guards the et.

Magic was widely used during epi-emics, which were on the increase by the cond millennium B.C. due to greater ntacts and trade outside of Egypt. The ague, an evil wind thought to be carried the breath of emissaries of the lion-eaded goddess Sekhmet, was treated on a tional scale. Some time during his reign, menhotep III erected a pair of giant li-ness-goddess statues for every day of the ear in a temple at Thebes; this was an ap-eal for Sekhmet's protection in warding f plague and disaster. Pinch suggests at, unfortunately, even royal interven-on proved no match for the plague, and it thought to have terminated this araoh's line by the end of the fourteenth entury B.C.

The subject of magic is so rich in an-ent texts and images that I missed not aving more elaboration of some of the arvelous particulars of practices, po-ons, spells, and incantations. But al-ough *Magic in Ancient Egypt* is not a ook that readers will breeze through, it is thorough and thoughtful treatment of a orld in which science, magic, and reli-ion coexisted.

ob Brier is chairman of the philosophy epartment at the C. W. Post Campus of ong Island University. He is the author of ncient Egyptian Magic *and* Egyptian ummies.



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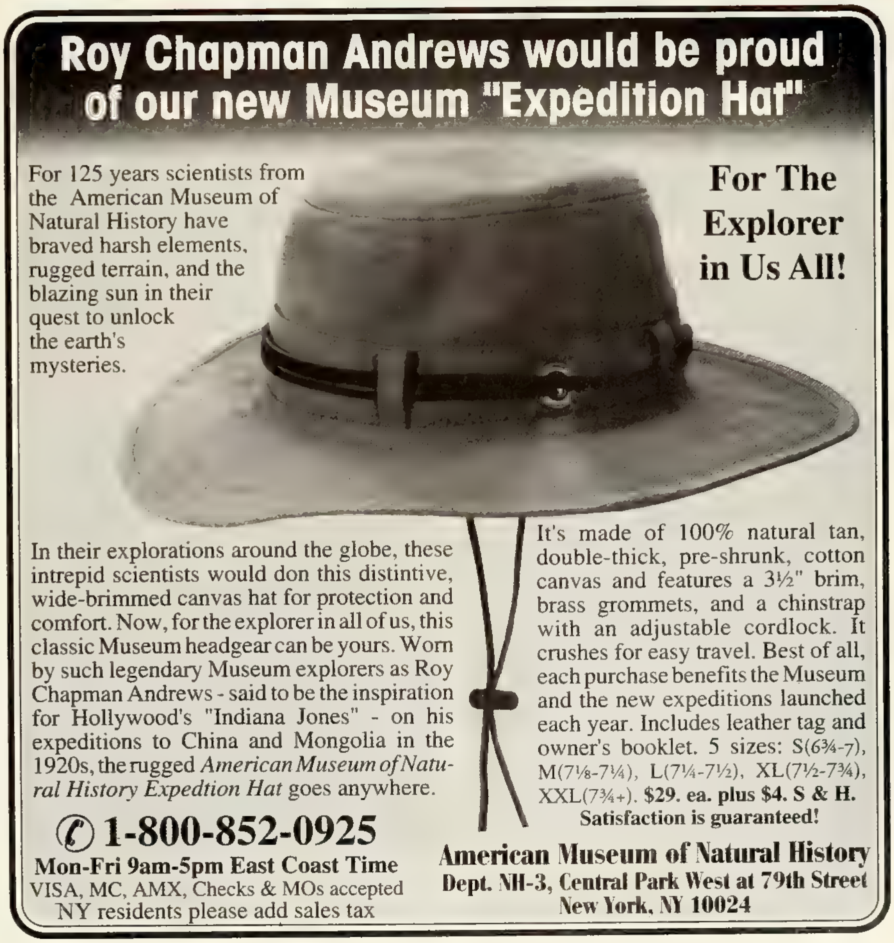

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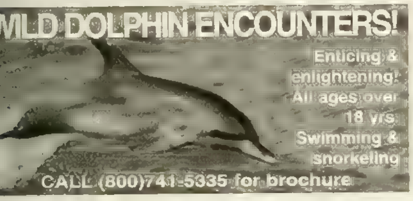

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A Yemeni melon vendor samples his wares.

Lorraine Matys

An Evening with Jane Goodall

Ethologist Jane Goodall will talk about her work with chimpanzees in Tanzania on Tuesday, April 25, at 7:00 P.M. in the Main Auditorium. Goodall, who established the Gombe Stream Research Centre in 1960, has been a pioneer in long-term primate study, bringing to world attention the various complexities of chimpanzee behavior, such as tool use, cooperative hunting, and aggression. Call (212) 769-5606 for information and ticket availability.

Northeastern Indians and Colonists

Responses of northeastern Indians to European colonists in America will be the subject of four consecutive Monday evening lectures by National Park Service archeologist Robert S. Grumet. The topics will include "Indian Diplomats and Warriors" on March 27, "Hidden Women Leaders" on April 3, "Culture Brokers and Go-Betweens" on April 10, and "Peacemakers and Warriors on the Eighteenth-Century Frontier" on April 17. Lectures take place at 7:30 P.M. in the Kaufmann Theater, and tickets for the series are $30. For more information, call (212) 769-5310.

The James Arthur Lecture

The sixty-fifth annual James Arthur Lecture, sponsored by the Department of Anthropology, will be given by neuroanatomist Este Armstrong on Monday, April 17, in the Kaufmann Theater. She will talk about how her work on advanced imaging techniques and geographical information systems applies to our understanding of the human brain. The lecture is free and begins at 6:00 P.M. Call (212) 769-5882 for further information.

The Library's Special Collections

On four consecutive Tuesday evenings beginning March 28, library director Nina Root and special collections manager Joel Sweimler will discuss the Library's natural history research collections. The lectures will be accompanied by rarely seen slides, films, and materials from the collections. Tickets for the series are $30. For more information, call (212) 769-5310.

Zebra Mussels: Alien Invaders

Zebra mussels, introduced accidentally into the Great Lakes in 1988 from the ballast water of a foreign vessel, have now spread east to the Hudson River, south down the Mississippi River to New Orleans, and as far west as Oklahoma. Sidney Horenstein, the Museum's coordinator of environmental public programs, will lecture on the invaders and their detrimental impact on the ecosystem on Wednesday, April 12, at 7:00 P.M. in the Kaufmann Theater. For additional information, call (212) 769-5606.

Museum Mystery Theater

On Wednesday, April 19, and again on Friday, May 5, the Education Department and the Manhattan Repertory Company will invite a Museum audience to help solve a mystery in the Hall of Northwest Coast Indians. In a drama that explores the traditions and culture of the fictional Bella Mons tribe, participants will try to piece together, from clues and partial information, the true story behind an ancient ceremonial mask. The program begins at 7:00 P.M. Admission is $20 and includes a wine-and-cheese reception. Call (212) 769-5310 for details.

The Galileo Mission to Jupiter

As part of the "Frontiers in Astronomy and Astrophysics" series, Torrence Johnson, senior research scientist at the Jet Propulsion Laboratory in Pasadena, will present a slide-illustrated talk, "The Galileo Mission to Jupiter." Tickets are $8 ($6 for members). Call (212) 769-5900 for information about all Planetarium events, includ
ing the Sky Show "The Ten Most Aske
Questions About the Universe" and the ex
hibition of images from the Hubble Spac
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The fate of the approximately 650 mour
tain gorillas in the rain forest ecosystems o
Rwanda, Zaire, and Uganda will be the sub
ject of lectures on two consecutive Thurs
day evenings, March 30 and April 6, at 7:0
P.M. H. Dieter Steklis, executive director o
the Diane Fossey Gorilla Fund and a profes
sor of anthropology at Rutgers Universit
will talk about the survival of mountain go
rillas, and will discuss the work he did as d
rector of the Karisoke Reserve before h
was forced to leave when the Rwandan w
erupted. Tickets for both lectures are $2
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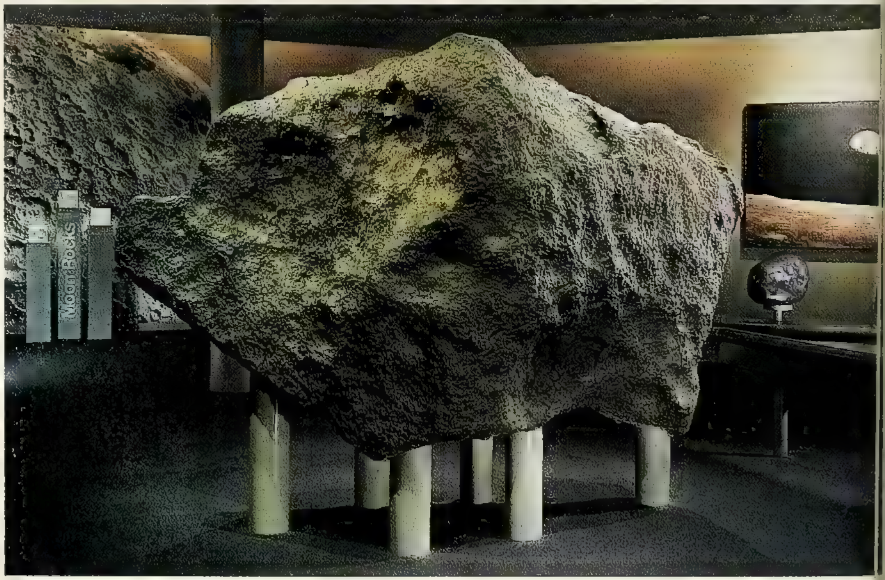
World Myths and Religions

The Department of Education is sponso
ing a year-long series "Unity Through D
versity." In April, the different belief sy
tems found throughout the world will be th
subject of lectures, films, and music ar
dance presentations. The programs inclu
a lecture on "The Power of Myth—and R
ligion" on Tuesday, April 4, and four sho



In 1894 Arctic explorer Commodore Robert E. Peary discovered this thirty-four-ton meteorite in Cape York, Greenland. Composed almost entirely of iron, it came from the core of a small planet that had fragmented in a collision with another planet about four and a half billion years ago. The meteorite is one of fifty treasures featured in the Museum's 125th-anniversary "Expedition" tours.

AMNH; Beckett/Chesek

ns about Bali and its culture on Sunday,
oril 9. On Tuesday, April 11, there will be
panel discussion about mythology as a
ulticultural bridge. On Saturday and Sun-
y, April 15 and 16, the Museum will pre-
nt a discussion on Balinese Hinduism; the
m *Releasing the Spirits: A Village Crema-*
n in Bali; a performance of the operatic
nce form, Ardja; a lecture on Balinese
own traditions in temple festivals; and a
ogram of Balinese masked theater called
peng. The programs are free with admis-
on to the Museum. Call (212) 769-5315
r a complete schedule of events.

RING FIELD TRIPS

The Education Department is sponsoring
number of spring workshops, field trips,
d walking tours outside the Museum.
entral Park, Sterling Hill Mine in New Jer-
y, New York's Palisades, the wetlands of
maica Bay, and Cape Cod are among the
aces to be visited. Call (212) 769-5310 for
complete listing.

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unded in 1921 to perpetuate the memory
this great American naturalist, maintains
s home, Slabsides, as a sanctuary in West
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r nature writing. This year's award goes to
raig Packer, author of *Into Africa*. Natural
story books for children and a natural his-
ry essay will also be recognized. The
ward luncheon will take place on Monday,
pril 3, at noon in the Leonhardt People
enter. Tickets are $30. Call (212) 769-
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The Museum will present two films by
avid MacDougal: *Photo Wallahs* on Fri-
ay, March 31, and *A Wife Among Wives* on
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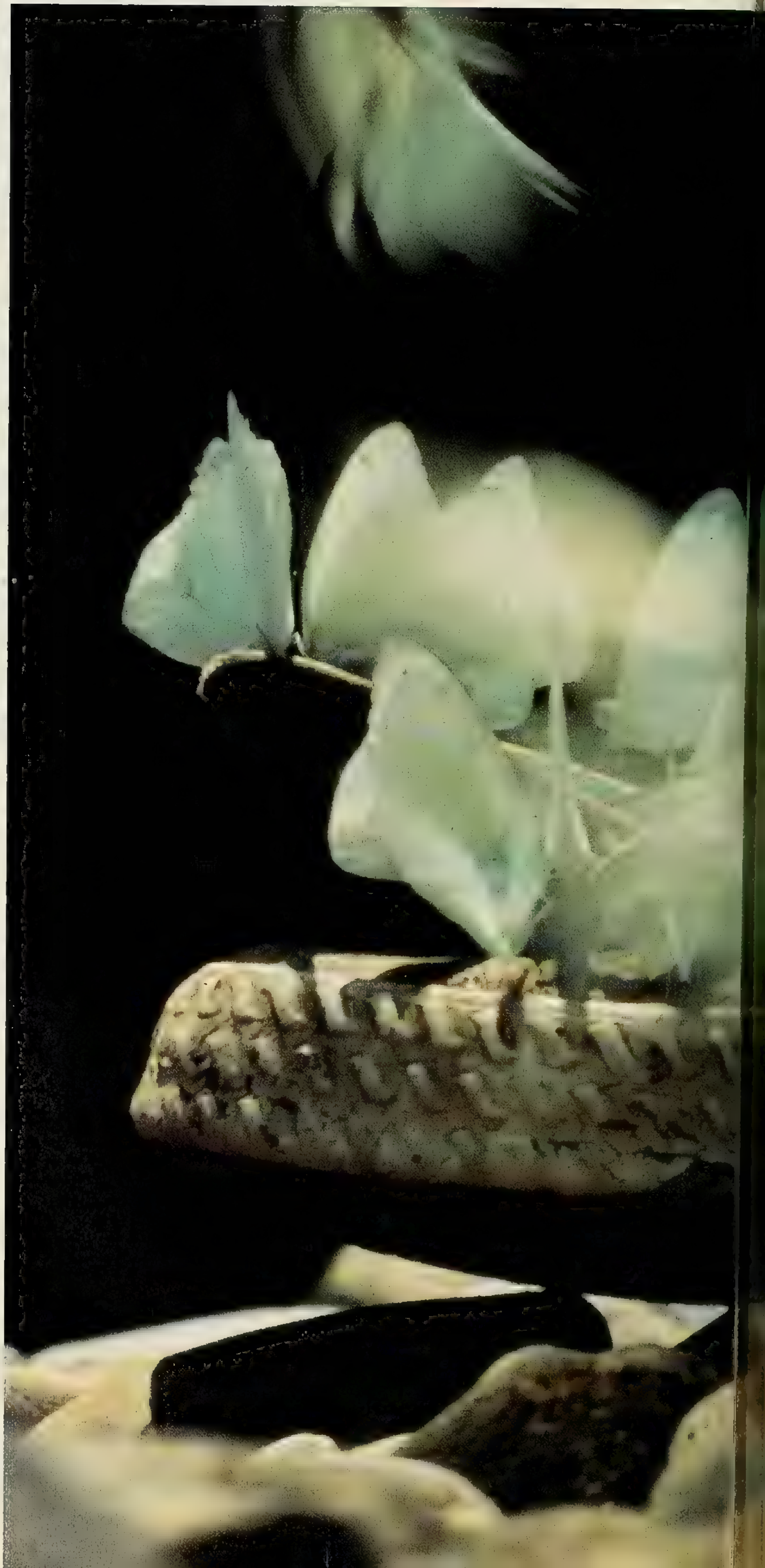

Set out to dry on an Amazon riverbank, a sweat-soaked sneaker attracts a group of pieridine butterflies. Surviving on nectar gathered from flowers, the butterflies need to augment their sugary diet with salts and compounds rich in nitrogen. These are found in human perspiration, but butterflies more commonly seek them on sandy banks, where water evaporating from puddles leaves the ground enriched in salts and other nutrients. The behavior is therefore referred to as puddling.

Butterflies are also attracted to saliva, urine, excrement, rotting fruit, and other nutritious substances. In the rain forest, a puddling mass of butterflies can easily be lured using these ingredients, but a decoy puddler, such as a small square of white paper, will help draw the first comers. Monkeys that frequent "restrooms" along stream banks create natural, streamside puddling areas that attract a profusion of butterflies and other insects. These gathering spots make good hangouts for large, predatory wasps and hungry jacamars and flycatchers, which can scoop up butterflies in midair.

Male butterflies puddle much more frequently than females, and researchers agree that the nutrients they gather add to their reproductive success. Biologist Karen Arms found that adult male tiger swallowtails look primarily for sodium, a salt that is scarce in the foliage they consume during their larval stage. Entomologist Robert Lederhouse and colleagues later found that given diets rich in sodium, potassium, calcium, nitrogen, and vitamins, laboratory reared male swallowtails mated more often than those given mere nectar. And the females the former group mated with produced more eggs, a higher percentage of which hatched and developed into strong adults. So the next time you see a butterfly sucking sweat from a sneaker, remember, it's probably a male enhancing his virility.—*R. A.*

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AUTHORS

About five years ago, **Terrence D. Fitzgerald** (page 30) brought some black cherry branches into his lab to feed the tent caterpillars he was studying. The tiny leaf rollers on the leaves attracted his attention, and he became curious about how the larvae managed to generate the forces needed to manipulate the leaves. He set up a time-lapse video camera to film the behavior and collaborated with research associate Karen Clark on a four-summer project to solve the mystery. "The leaf-rolling interlude," as Fitzgerald calls it, has come to an end with the publication of their findings, and he is back to full-time study of chemical communication in tent caterpillars. A professor of biological sciences at the State University of New York at Cortland, Fitzgerald has just completed a technical book on tent caterpillars that will be published by Cornell University Press this year. His most recent distraction is a hand-reared male starling which he allows to fly freely around his office. He boasts that "it was able to whistle the first eighteen notes of a sea chantey at the age of six months and has vocabulary of twelve words."

"I grew up in the dry sheep country of Australia," writes zoologist **Terry Dawson** (page 38) "and was always fascinated by the natural history of its birds and mammals. When I did postdoctoral work at Duke and Yale in the 1960s, I was surprised to learn that marsupials, including kangaroos, were considered 'primitive' mammals with poorly developed thermoregulatory abilities. This did not sit well with my own boyhood observations. For the past twenty years or so, I have been examining this discrepancy." As he amply demonstrates in his article, the heat-loss physiology of red kangaroos easily outperforms that of such "advanced" mammals as sheep. Althoug he has been a visiting professor at four American universities, Dawson has spen most of the past twenty-eight years at th University of New South Wales, where he has helped develop special facilities for studying kangaroos and other native Australian animals. At Fowler's Gap, in the dry rangelands of New South Wales, the university maintains an arid zone research station of roughly 100,000 acre which has been Dawson's second home and the site of most of his fieldwork. Fo species of kangaroo live there, including about 6,000 red kangaroos. When he is not working in the desert, Dawson enjoy racing his fifteen-foot skiff in Sydney Harbor, fishing, and attending operas. Fo additional reading he suggests Terry Domico's *Kangaroos: The Marvelous Mob* (New York: Facts on File, 1993) ar his own recent book *Kangaroos: The Biology of the Largest Marsupials* (Ithaca: Cornell University Press, 1995).

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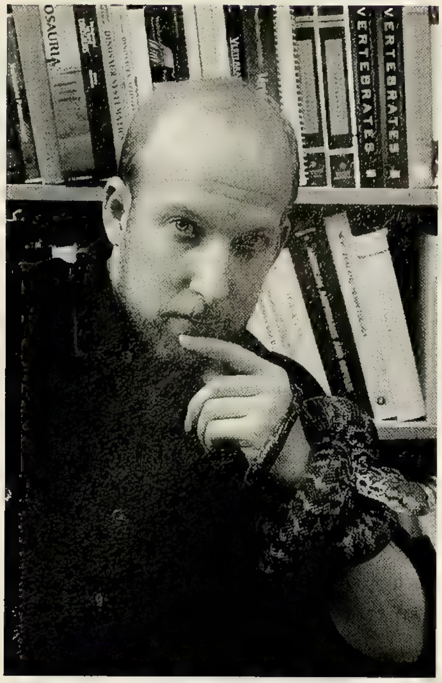
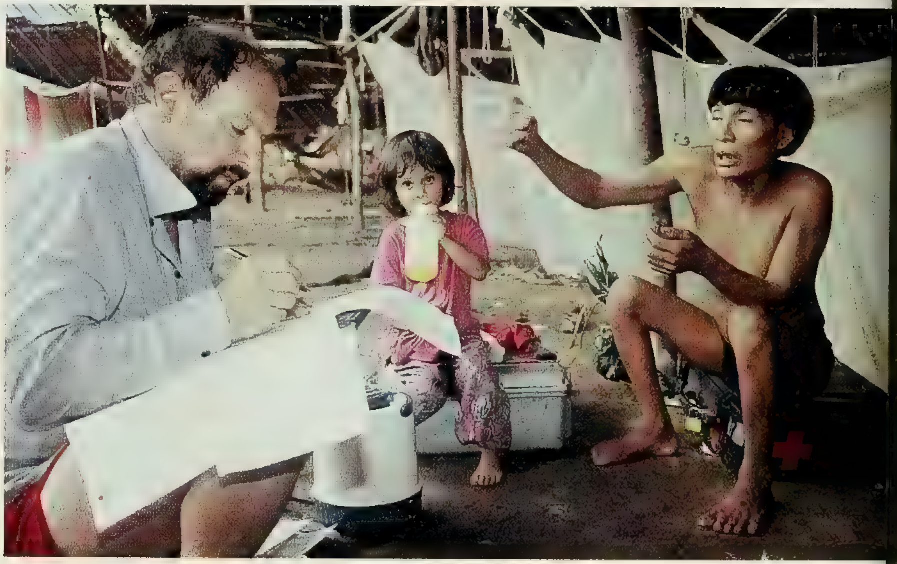


Kurt Schwenk (page 48) says that unlike most herpetologists, "who seem to start collecting snakes soon after birth," he developed a passion for reptiles relatively late in life. His original interest, as a junior at Oberlin College, was the feeding mechanisms of lizards. Between college and graduate school, he worked as a zoo keeper at the Bronx Zoo, where he developed some hands-on experience with animals of all sorts. With his academic learning thus enhanced, he pursued a doctorate in zoology at the University of California at Berkeley, with a dissertation on the morphology of lizard, snake, and tuatara tongues. Now an assistant professor of ecology and evolutionary biology at the University of Connecticut, Schwenk has recently been promoted and looks forward to September of this year, when he will officially be a tenured associate professor. He plans to continue his research on lizards and snakes, with a particular emphasis on how form and function are integrated in an evolving lineage of animals. No reptile can compete, however, with his five-year-old son, who satisfies simultaneously his interest in children and natural history. For more on snakes, readers might turn to *Snakes: Ecology and Behavior Biology,* edited by Richard A. Seigel and Joseph T. Collins (New York: McGraw Hill, 1993). Snakes from "down under" are well covered in Richard Shine's *Australian Snakes: A Natural History* (Ithaca: Cornell University Press, 1992).

Kenneth Good (page 56) went to Venezuela with plans to study the Yanomami of Hasupiweteri for fifteen months and ended up staying with them for twelve years. His personal odyssey is detailed in his book, coauthored with David Chanoff, *Into the Heart: One Man's Pursuit of Love and Knowledge Among the Yanomama* (New York: Simon and Schuster, 1991). While living with the Yanomami, Good learned that their extended treks into the forest to hunt and gather wild foods were a crucial part of their strategy for survival. Good is now an assistant professor of anthropology at Jersey City State College. For additional reading, he recommends "Trekking in the Amazon Forest," by Dennis Werner (*Natural History,* November 1978), and *Indigenous Peoples and the Future of Amazonia,* edited by Leslie Sponsel, which will be published by the Universit of Arizona Press later this year.



With a young macaw resting on his shoulder, **Frans Lanting** (page 88) gets ready to snap a picture. The bird became habituated to people while Lanting and others were on an expedition to study and photograph wild macaws in the rain forests of the Peruvian Amazon. As a university student in Holland and the United States, Lanting studied environmental planning and environmental economics, but since 1980, he has been traveling the world on a variety of freelance photography assignments. Largely self-taught in biology and photography, Lanting is also a roving editor for the National Wildlife Federation and an editorial consultant to World Wildlife Fund Holland. He used a Nikon FE2 to photograph this month's "Unnatura Moment"—a butterfly-infested sneaker. After arriving back in camp after a long day of observing macaws in the forest canopy, he and his colleagues set clothing out to dry on a gravel riverbank; the sweat-soaked sneaker attracted a horde of the winge insects.

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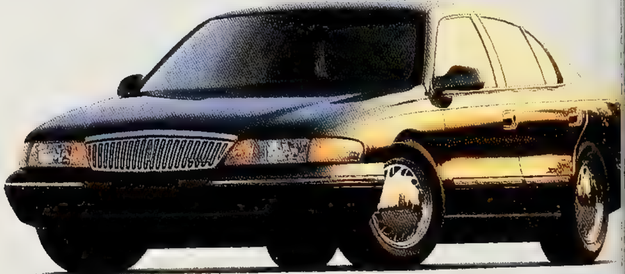

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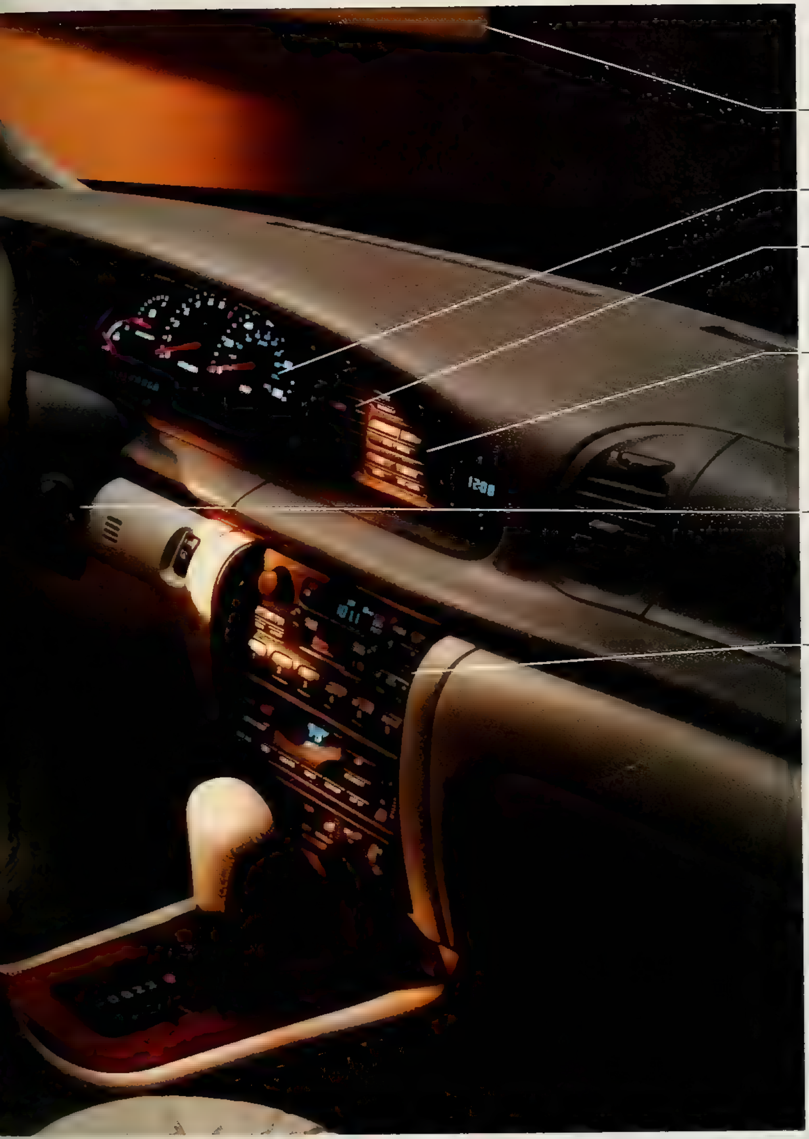

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Co

COVER: A bull hippopotamus gapes, perhaps to intimidate rivals with a display of its daggerlike canine teeth. The social and dietary habits of the species are fully revealed only to observers willing to stay awake nights. Story on page 46. *Photograph by Christine and Michel Denis-Huot.*

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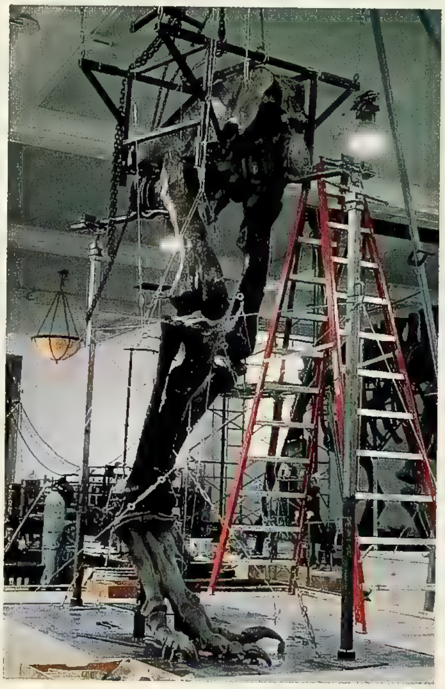

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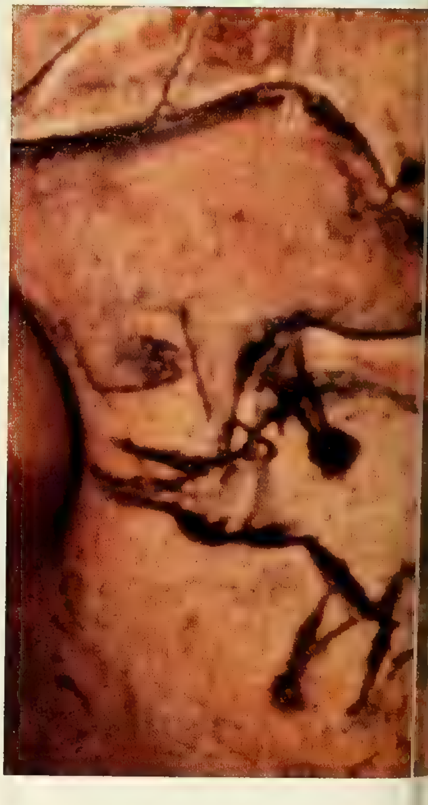

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SPIDER VERSUS SKINK

The picture of a wheel spider dispatching a gecko ("Spider Revolutions," March 1995) reminded me of the time an immature blue-tailed skink gained entry into my house and began patrolling the baseboard near the web of an American house spider.

Although I was pleased to have attracted such a beautiful reptile, I worried about the safety of the spiders, which kept in check the household's population of roaches, flies, wasps, scorpions, and such. I therefore watched the skink's whereabouts carefully, pledged to remove it if I found that it was destroying webs.

One evening as a friend and I sat down for dinner, I pointed to the place where the skink normally patrolled, but the lizard was gone. We scanned the baseboard, expecting the worst, and, indeed, discovered the skink in a web. Closer inspection, however, revealed that the skink had become the prey. Trussed up tightly, the skink received dose after dose of venom under its jaw over the next several hours until it stopped twitching.

After two days of feasting, the spider, looking extremely fit, flicked the shriveled carcass from the web and resumed its watchful position.

STEVE JONES
Dahlonega, Georgia

STILL-RELEVANT STONE MEN

I enjoyed Fred Bruemmer's article ("Sentinels of Stone," January 1995) on the Inuit stone figures known as inukshuit. Once, when climbing a hill near Kangiqsujuaq (Quebec), I came over a crest to find myself being targeted by a kneeling hunter with a rifle. To my great relief, the hunter turned out to be an inukshuk adorned with a broken hockey stick. It therefore does not surprise me that caribou avoid the stone men.

While caribou drives using the cairns have been rendered obsolete by repeating rifles, inukshuit are neither irrelevant nor forgotten. In northern Inuit communities, subsistence hunting provides at least one-third of all calories and "country foods" are highly valued and recognized as important to physical and psychological well-being. One must still get to where the caribou (and fish, walruses, and seals) are, and inukshuit still stand out on the horizon as important navigational markers to hunters in snowmobiles and boats.

CHRIS FLETCHER
Blanford, Nova Scotia

FLYING CHICKENS

Robert Mohlenbrock's article about fire and prairies in Michigan ("This Land," March 1995) reaffirms what we learned about fires and prairies in the old Lake State's lumbering days a century ago.

I have one question though. Since when did prairie chickens become "flightless"? When I shot at them with my father fifty years ago, they flew out of sight.

FREDERICK C. PULLMAN
Little Compton, Rhode Island

Prairie chickens do indeed fly. We apologize for the error.—*Eds.*

SODA POP

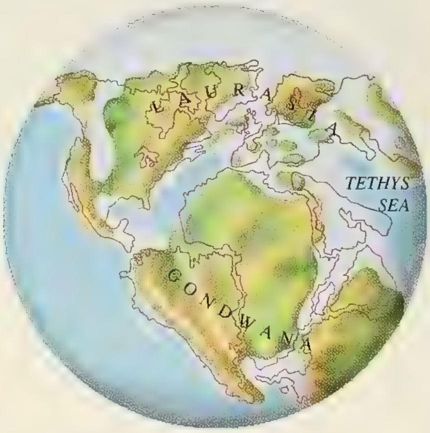
The phrase "I would like a cup of ice and soda" in Roger Welsch's February 1995 "Science Lite" column reminded me of a language difference that I first became aware of when I moved to the Pacific Northwest in 1980. Having grown up in upstate New York, I use the term "soda" to refer to such soft drinks as Coca-Cola, Pepsi, and Seven-Up. But in Washington State, I found that the term "pop" (as in "soda pop") was used instead. "Soda" to a Pacific Northwesterner means carbonated water ("seltzer" or "Vichy" back east).

Years later, on a cross-country drive from east to west, I remembered the soda versus pop dichotomy and kept track o where the transition took place. I found that just west of Buffalo, New York (colonial America's western frontier), pop replaced soda as the term of choice. Depending upon what Nebraskan Roge Welsch meant when he asked for his soda I wonder if he is a transplanted Northeasterner.

RAYMOND HV GALLUCC
Richland, Washingto

Roger Welsch, a native Midwesterne says he meant to write "pop." In using th word "soda" he gave in to a "momentar affectation of sophistication."—*Eds.*

Jurassic Landmasses



In "Dinosaurs and Drifting Continents" (January 1995), the label "Gondwana" was incorrectly placed on the map on pages 1 and 42. Only the southern continents should have been so labeled. Natural History *regrets the error and corrects the map, above.*

UNDERRATED TONGUE WORMS

Stephen Jay Gould understates the pos sible popular interest in pentastomes, o tongue worms, in his January colum ("This View of Life"). Given that some o the more important modern hosts o tongue worms include crocodiles, alliga tors, and sea birds, a paleontologist migh speculate that pentastomes may have pa asitized the dinosaurs.

More than a few species of tongu worms use fishes as intermediate hosts. have seen these parasites in freshwater an brackish-water fishes, including large mouth and peacock bass in Puerto Rico, well as in Pacific coral reef fishes. Th close relation between pentastomes an branchurians (argulids, or fish lice, whic are principally fish parasites) suggests th fishes—not terrestrial vertebrates—ma once have been the definitive hosts of pe tastomes.

ERNEST H. WILLIAMS, J
Magueyes Island, Puerto Ric

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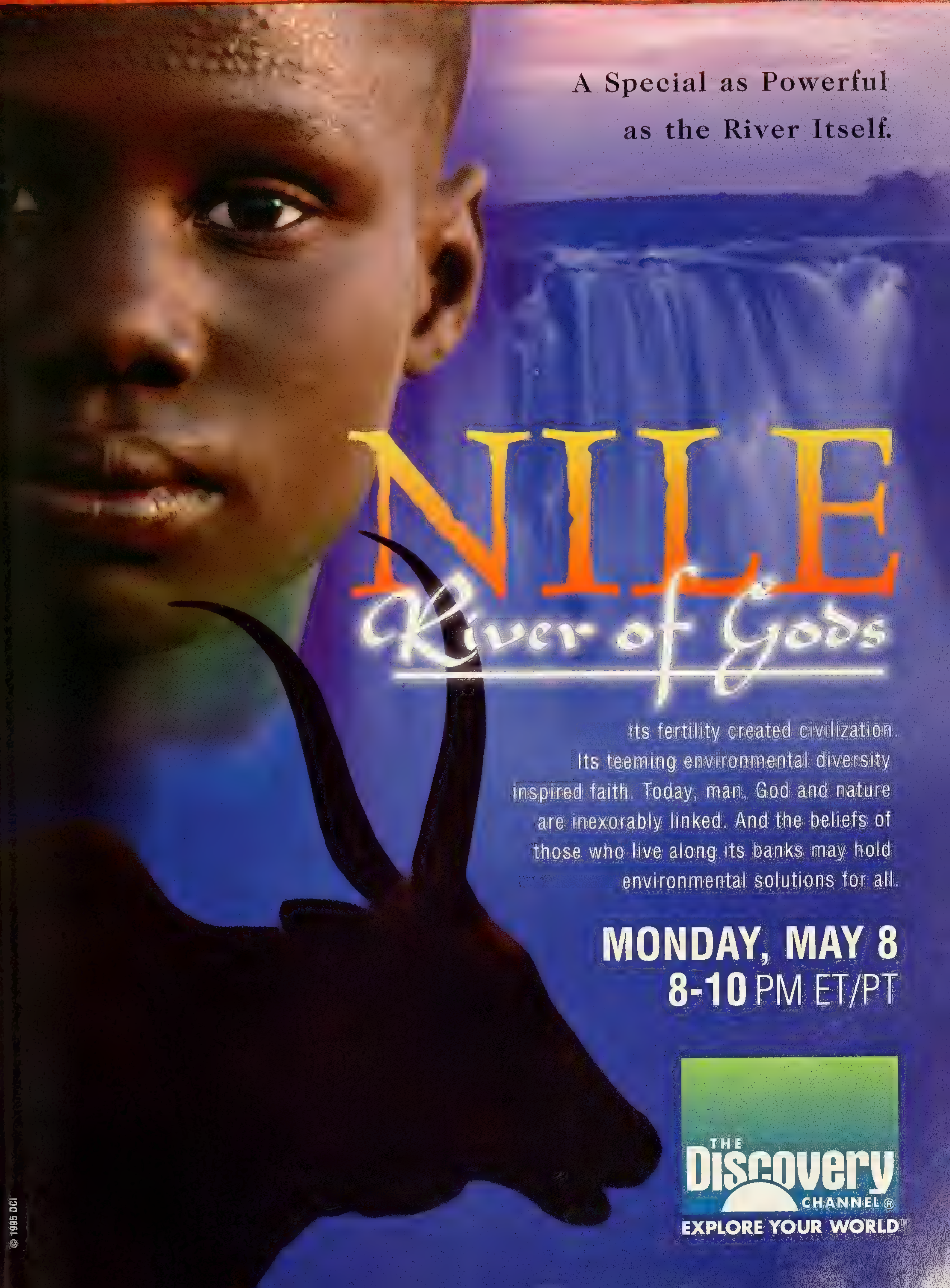

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Bringing Back the Dinosaurs

by Richard Milner

"Large dinosaur bones," says Lowell Dingus, director of the American Museum's fossil hall renovation, "are extremely heavy, remarkably fragile, and utterly priceless." During the past four years, Dingus's staff has dealt with thousands of them during a massive, $34 million overhaul of the American Museum of Natural History's halls of fossil mammals, reptiles, amphibians, and fishes. Approximately 100 skeletons will be featured in the newly refurbished dinosaur displays, making this the most comprehensive exhibition of Mesozoic memorabilia anywhere. Even so, the skeletons to be exhibited will represent only 5 percent of the Museum's unrivaled collection of 2,000 fossil dinosaur specimens.

When the imperious Henry Fairfield Osborn founded the American Museum of Natural History's vertebrate paleontology department in 1891, the Museum did not have a single dinosaur. He promptly bought up collections, sent field crews out to gather more, and created a new concept for museums by having skeletons of extinct animals mounted in realistic poses. Until then, most museums merely exhibited their slabs of fossils pretty much as they came from the quarry. A bronze bust of Osborn at the Museum bears the legend: "For him the dry bones came to life, and giant forms of ages past rejoined the pageant of the living."

Shortly before the turn of the century, a young artist named Charles R. Knight began painting extinct animals for the Museum, and Osborn commissioned him to undertake huge murals for the halls of fossil mammals. Knight also created the definitive images of dinosaurs in a series of classic paintings exhibited near the fossil reptiles. So popular were these halls that visitors lined up for hours for a glimpse of the earth's prehistoric past. Soon Knight's images of mammoths and dinosaurs leapt off the Museum's walls to enter popular culture. Comic-book artists, toymakers, and filmmakers have copied and recopied his upright tyrannosaurs and sluggish, swamp-dwelling brontosaurs ever since.

Today dinosaurs are more popular than ever, although some of the scientific thinking about them has changed. Many paleontologists now see these animals, which dominated the fossil record for 140 million years, as more active, social, and diverse in their habits than had previously been supposed. New evidence suggests that some were herd animals, that others may have been good parents, and that all our modern birds are descended from small, carnivorous dinosaurs. With recent discoveries of new species, along with intensive work on cladistics (the study of branching evolutionary relationships), Museum scientists are continuing to puzzle out just how the various dinosaur groups arose and diversified.

Two halls of fossil reptiles—which include the American Museum's famous dinosaurs—will reopen on June 2, 1995. Closed to the public since 1991, the refurbished **Hall of Saurischian Dinosaurs** and **Hall of Ornithischian Dinosaurs** will contain the largest display of fossil dinosaur specimens in the world.

Soon after the fossil hall restoration was announced, Dingus assembled three special groups to undertake the transformation. Phil Fraley, a versatile preparator who worked with Dingus at the California Academy of Sciences, headed a crew that would mount or repair the skeletons; Steven Warsavage directed the installation group; and Jeanne Kelly, of the Museum's vertebrate paleontology lab, supervised six preparators who were to clean and conserve the specimens.

"My staff for the mounting and renovation of skeletons was made up of artists and sculptors," says Fraley, "because they tend to be people who have trained themselves in a wide variety of occupations and technologies." Fraley hired five sculptors with diverse skills in metalworking, welding, and fine arts. Some had worked at ar foundries, while others had created sculptures in public parks and even conceptua art (such as the geometric forms tha sculptor Dion Kliner once buried in concrete containers "to prevent any meaning from seeping in"). None had ever been especially interested in fossils or dinosaurs rather, they were chosen for their experience and ingenuity in fabricating durable three-dimensional art. During their stint i the mammal halls, the artists learned t work with the curatorial staff. "The designers had their concept," said one crew member, "the curators had the scientifi requirements, Phil had his own ideas, an we had to try to satisfy them all. Finishe pieces rarely turned out to be what any o them had expected, but they were usuall happy with the results."

Before Fraley's group could begin making steel supports for any of the foss mammals or reptiles, Kelly and he preparators had to clean all 300 spec mens, removing dirt and varnish, whic often clogged delicate structures. The then coated each bone with plastic dilute in acetone, a mixture that preserves th finest details. Many of the old skelet mounts were still usable, but Fraley's cre needed to completely dismantle and reposition five specimens, because knowledg about the creatures had changed.

Among those needing major overhau were the gigantic *Tyrannosaurus rex* an

James Joern

Apatosaurus (formerly known as *Brontosaurus*) skeletons. Crew members Richard Webber, Dion Kliner, Larry Lee, Paul Zawisha, and Matt Josephs worked with Fraley to disarticulate the old king of the tyrant lizards. For decades it had been standing up on two legs, with its tail dragging on the ground—a pose no longer consistent with scientists' understanding of how the creature moved. Since current research holds that birds are the closest living relatives of extinct dinosaurs, the great meat-eater had to be posed more like a road runner, with its head thrust forward and tail held well above the ground.

"Moving around these tons of dinosaur bones," said Fraley's assistant Paul Zawisha, "one quickly learns to appreciate their extreme fragility. When we first worked on the mammoths in the mammal halls, we removed a metal clamp from one of the tusks and it exploded like a firecracker. Ribs are crystalline inside and shatter as easily as icicles." Special care was taken when moving the fossils; workers even used special high-tech carts whose wheels don't wobble or vibrate. Remounting large dinosaurs is especially nerve-racking, as it requires hoisting extremely heavy, fragile objects high above unforgiving concrete floors. During the renovation, the crews acquired a great deal of respect for the original preparators of a century ago, who had to confront the same problems without today's technology.

Before any adjustments to the tyrannosaur were attempted, crewman Matt Josephs built a small scale model in a new, low-riding, running pose. After the miniature received curatorial approval, the real tyrannosaur had to be remounted in that position. To disarticulate and reposition the dinosaur, each step had to be carefully planned in advance. Sometimes one small movement required weeks of engineering—calculating torques, stresses, and metal fatigue. Giant A-frames were constructed, complicated rigging was erected all around the mount, and individual sections were surrounded with specially built containers, or cradles.

The crew spent weeks rigging superstructures, until the pelvis, legs, and other elements were suspended from cables and could be moved around with one finge
(The tyrannosaur pelvis alone weigh
2,000 pounds.) Once the bones' final pos
tions were decided upon, the crew neede
to construct an armature, or steel brac
that would follow each twist and turn i
the new mount, support most of its weigh
and lock everything in place.

Shaping an armature for small skel
tons is a relatively simple, but exactin
task. Heating thin steel pipes with a torc
the preparator curves them so they will u
obtrusively support the vertebrae, rib
and legs. During the shaping process, th
must continually be placed alongside t
bones to achieve a custom fit. To prote
the original fossils from damage whi
working with hot metal, the artisan oft
substitutes plaster casts of the bones. Wi
the full-scale dinosaur mounts, the proce
is similar but much more perilous. T
legs and pelvis, for instance, must be su
ported by heavy steel pipes that are shap
using very high heat. Even plaster casts
the bones were prone to burn and crack
hot steel was bent around them. So t
crew cast copies of the legs and pelvis i

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Left: The dinosaur renovation crew gathers around foreman Phil Fraley for a group portrait. Leaning against the tyrannosaur are Larry Lee, Paul Zawisha, and Richard Webber. In the front row are Dion Kliner, Fraley, and Matt Josephs, holding an acetylene torch.

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Forming the armature for a Panoplosaurus *skull, Richard Webber, above left, cuts a piece of steel. After scaffolding was erected around the old tyrannosaur, above, its arms and feet were removed. Dion Kliner and Phil Fraley, left, adjust a repositioned foot.*

refractory cement, a substance used to line foundry furnaces. "It looks like concrete but won't crack or crumble under very high heat," crewman Richard Webber explained. "With these special copies, we were able to form and weld our steel armatures without worrying about harming any real dino bones." Now the tyrannosaur, poised to hunt prey, faces the front of the hall, where visitors will enter.

Because species are now grouped by evolutionary relationships, the apatosaur and the tyrannosaur, which were not formerly exhibited near each other, have become roommates. Although the two species lived at different times, as saurischian dinosaurs they are fairly close relatives.

With its head and tail removed, the apatosaur weighed about seven tons, and Kelly's conservation team had the task of cleaning and preserving it in place. To give preparators easy access to the giant without having to climb scaffolds and ladders, Warsavage's installation crew built a two-story house—complete with walls, floors, joists, stairways, and doors—around the apatosaur. Before the skeleton was moved, the conservators carefully checked every bone for fatigue cracks and stabilized the surfaces with liquid plastic. Finally, the massive skeleton, "house" and all, was moved by electric winch to its new position on the opposite side of the hall. But now that the apatoasaur was cleaned and preserved, it was in for some overdue changes.

Skeletons are rarely found complete, so museum mounts are usually composites of several individuals. Originally assembled in 1905, the apatosaur contained a few mistakes. For one thing, its tail had been reconstructed trailing on the ground, but subsequent discoveries of fossil trackways clearly showed that the animal did not drag its tail. As more apatosaur skeletons were found, other inaccuraces in the old mount became apparent: the tail and neck were too short, and the dinosaur had been sporting the skull of a related species, *Camarasaurus,* for the better part of a century. Vertebrae were added to the now-suspended tail, increasing the skeleton's length to eighty-six feet—about twenty feet longer than the original version. The wrong skull was removed and a proper one set in place.

Another major challenge was to move the trackway of fossil footprints that had long been exhibited behind the apatosaur. R. T. Bird had collected these fossilized footprints in 1938 at Texas's Paluxy River. His boss, the famed dinosaur collector Barnum Brown, had ordered him to focus on finding bigger and better skeletons, but Bird's passion was for trackways. Fossil footprints spoke to him about how the animals behaved: their habit of traveling in herds and their manner of locomotion. He eventually succeeded in quarrying for the Museum an especially interesting sequence of footprints, in which a meat-eating dinosaur appears to be following or stalking a giant vegetarian.

But Bird's treasured trackways were improperly stored for fifteen years, and their identification numbers had been lost. In 1953, when paleontology curator Edwin Colbert decided to place the remarkable sequence of footprints behind the apatosaur, he summoned R.T. Bird out of retirement to direct its assembly. The

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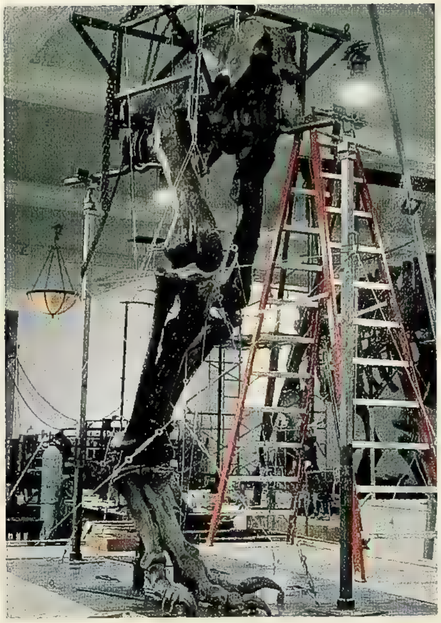

The tyrannosaur's pelvis and limb elements, left, are suspended for adjustments to its final pose. Below, left: Using an acetylene torch, Dion Kliner bends steel for bracing a Lambeosaurus *skeleton. Larry Lee, below, connects steel braces to an* Iguanodon *skull. Right: While Matt Joseph works on a small fossil skull, Paul Zawisha (on ladder) repairs the tyrannosaur's tail.*

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task was similar to solving a giant jigsaw puzzle in which each piece weighed a ton.

Now, more than four decades after the trackway was reconstituted, installation supervisor Steve Warsavage says, "we had to spin the whole thing around and put it at the other end of the hall. Well, how do you do that when it weighs approximately twenty-two tons and is falling apart?" Each block had been propped up with bits of plaster and blocks of wood. Although it looked like a unit because of a thin plaster coating, Warsavage knew it would not cohere. "First," he recalled, "we got thick steel plates, beveled the front of them, coated their bottoms with molybdenum grease, and drove them underneath the trackway blocks. You've seen how magicians pull a tablecloth out from underneath the silverware and plates? Well, this was like putting the tablecloth back underneath, without disturbing the plates and silverware." Finally, Warsavage's crew enclosed the trackway within a welded steel frame, then covered the floor with dishwashing liquid. Despite the mumblings of some skeptics, they were able to slide the whole twenty-two tons as a unit and place it easily right behind the apatosaur.

The tyrannosaur and apatosaur are now part of a comprehensive sequence that, when completed, will form a consistent evolutionary scheme for the six fossil halls. Such exhibits can be organized either as a walk through time or as an evolutionary tree. Most older museum exhibits group animals of the same time period in each hall, regardless of their kin relationships. "We chose to do the evolutionary tree motif," says paleontologist Dingus, "because it enables us to showcase current scientific research while demonstrating dramatically that we're all connected by this tree back to the original vertebrates."

In many museums, dinosaur halls contain mostly fiberglass casts, some of which are produced at the American Museum's reproduction studio and sent all over the world. "In many instances where they do have actual specimens," says Dingus, "they prefer to keep them off the exhibition floor—either for security reasons or because visiting scientists want the originals available for research. But the curators here want the real material on display. About 85 percent of what you see is the real thing, since some reconstruction of missing pieces is always necessary. Our tyrannosaur exhibit includes the first skul ever collected of the animal. Discovered by Barnum Brown and Peter Kaisen nea Big Dry Creek, Montana, in 1908, it wil be in a case below the mount, so tha people can get up close to examine it."

Although many visitors cannot tell the difference between fossil bones and casts Dingus insists that exhibiting original material matters. "If you went to your favorite art museum to see a Gauguin, and were told, 'Well, it's not the real thing, but it's good reproduction,' you'd be disappointed. Putting the real specimens ou there shows the public that there is hard overwhelming evidence for evolution Fossils, as well as modern genetic an anatomical studies, tell us that these animals really lived, that we share commo ancestors with them, and that their descendants can still be seen visiting our bir feeders. People often ask, 'Are those dinosaurs real?' We're one of the few place that can answer 'yes, they are.' " □

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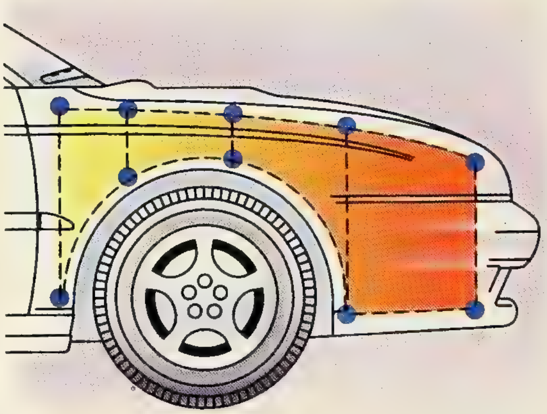

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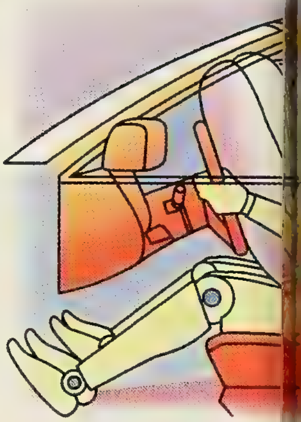

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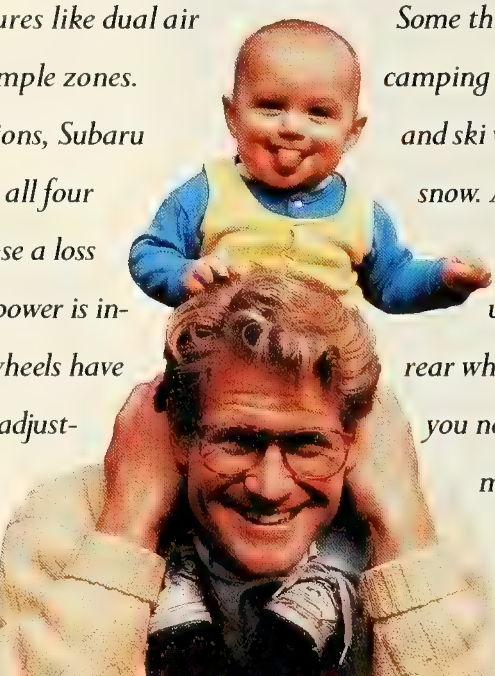

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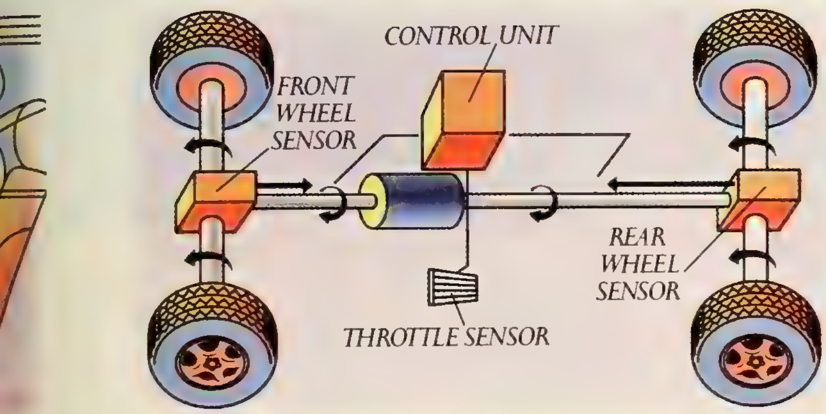

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Speaking of Snails and Scales

In mollusks, as in mother tongues, less complex doesn't necessarily mean more primitive

by Stephen Jay Gould

The psalmist asked: "What is man, that thou art mindful of him?" We have searched, no doubt vainly, for a nature or essence of humanity ever since we evolved enough cognition to ask. Just consider the variety of classical responses, each emphasizing a central part of the human totality. "A reasoning animal," said Seneca, honoring an aspect of our mental life. "A political animal," proclaimed Aristotle, focusing upon our social instincts. "One name belonging to every nation. . . one soul through many tongues," wrote Tertullian, signaling our unity of diversity. We should also not forget the famous definition, attributed to Plato and based on overt appearance in contrast with other vertebrates: "A featherless biped." (According to legend, Diogenes the Cynic plucked a cock and brought it to the Academy, proclaiming, "Here is Plato's man." The old definition then received an addendum: "with broad flat nails.") All in all, however, I favor the celebrated and much later definition of Blaise Pascal, for he emphasized our sublime weakness: "A thinking reed."

No one-liner can ever be optimal, but my preferred characterization at least has the virtue of combining in one descriptor all the elements cited above—our social needs, cognitive abilities, uniqueness among animals, and unity amid variety. Human beings are storytellers, spinners of tales.

We gather the complexities of our world into stories; we give order to the confusion of our lives, and to the apparent senselessness or cruelty of our surroundings, by constructing narratives that imbue the totality with meaning. This propensity to tell stories grants us resolution, but also spells danger in avenues thereby opened for distortion and misreading. For our favored stories unroll along definite and limited pathways (we call them epics, myths, and sagas, and they often show eerie similarities across disparate cultures), and we often try to channel a much more varied nature along these familiar and edifying routes.

Since all discovery emerges from an interaction between mind and nature, thoughtful scientists must scrutinize the many biases that record our socialization, our moment in political and geographic history, even the limitations (if we can hope to comprehend them from within) imposed by a mental machinery jury-rigged in the immensity of evolution.

We are most attuned to obvious biases of a social or political character. We can easily grasp how racism has distorted our view of human diversity, or how creationism once precluded any adequate understanding of life's history. We have been less likely to recognize the subtler, but equally constraining, prejudices that arise from more universal properties easily hidden by their lack of evident variation across cultures and classes. Into this less visible category, I would place our tendency to order complex reality into stories with restricted themes and outcomes. I call this propensity "literary bias." Anton Chekhov wrote that "one must not put a loaded rifle on stage if no one is thinking of firing it." Good drama requires spare and purposive action, sensible linking of potential causes with realized effects. Life is much messier; nothing happens most of the time. Millions of Americans (many hotheaded) own rifles (many loaded), but the great majority, thank God, do not go off most of the time. We spend most of real life waiting for Godot, not charging once more unto the breach.

A particular class of stories holds special power to distort by combining the standard form of sociopolitical prejudice with subtler literary bias. Our conventional explanations of historical sequences tend to be regulated by the primary sociopolitical theme of Western life since the late seventeenth century: the idea of progress, with corollaries of movement from small to large, simple to complex, primitive to advanced; and an ideal of perpetual growth and expansion. When we add our more general storytelling preferences, our literary biases for narrative continuity between stages and causal unity of transforming forces, we obtain the standard format for historical stories: purposeful, directional, and sensible change. Given the failure and inadequacy of so many tales in this mode—the pageant of prehistoric life from monad to man

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Marx's theory of historical stages toward a communist ideal—we must begin to wonder how often nature deigns to venture even close to our hopes for her patterns.

In any case, our standard historical stories of meaningful progress do not stand as mere abstractions; they are heuristic devices that strongly encourage scientists to proceed in a certain way. In particular, such stories virtually dictate that complex systems can best be understood by searching for a simpler state, an earlier stage, or a more primitive version to serve as a comprehensible model for a more intricate reality at present beyond our grasp (study my pea patch and you might eventually fathom agribusiness). Darwin scrutinized a few hundred generations of pigeon breeding to model the history of life over millions of years; earlier generations of anthropologists, in their more than mildly racist language, scoured the earth for "primitive" peoples who, in the simplicity of their commerce and social relations, might stand as surrogates for early stages of Western urbanity.

These differently complex, non-Western cultures are fascinating in themselves; so too, believe it or not, are pigeons. Events of small scale or short times should be studied in their own right. But the exploitation of such events as early stages in a narrative of rising complexity may backfire because causal continuity often fails. Small and short are often just different from big and long, not little brothers gliding toward a more intricate manhood.

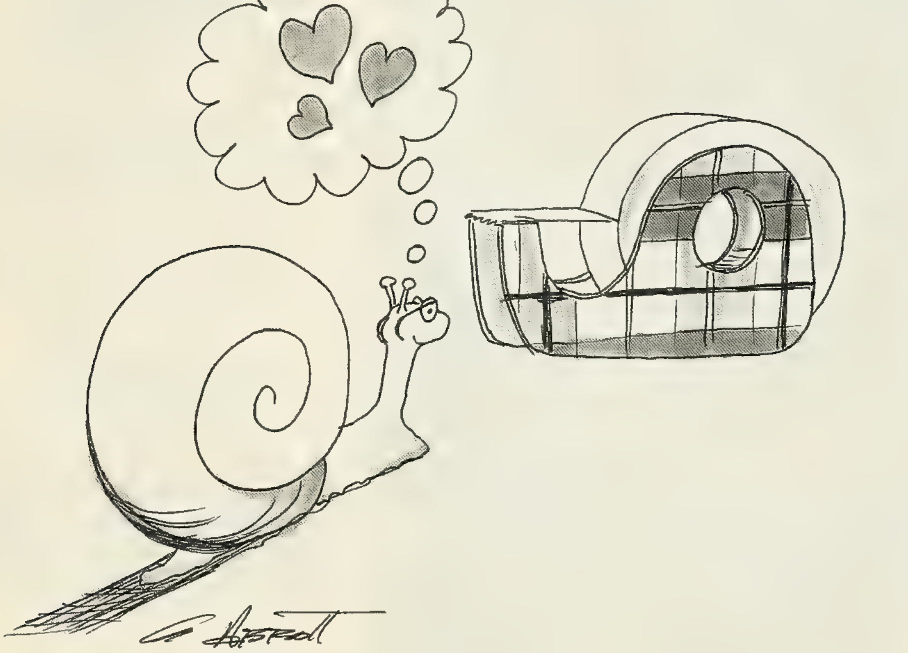
To illustrate this theme of misconstruing the less complex as the primitive precursor, I want to tell a story about a scientific misjudgment of my own early career. In 1969, I first visited the island of Curaçao (off the coast of Venezuela) to study the land snail *Cerion uva* (I will mention later why I chose this peripheral island in the general distribution of *Cerion*). Just last month, I traveled to Curaçao again for the first time in more than twenty years. (I will also recount the purpose of this visit later. Essays are stories, and I am therefore permitted the literary devices of foreshadowing and mild mystery.)

Curaçao is a land of mixtures and contrasts. As a Dutch island off Spanish South America, a cactus-filled desert in the Caribbean tropics, Curaçao has melded its disparate parts into a distinctive culture. Consider the anomalous mixture of oil and sun. Curaçao's geology and geography have set its destiny. The periphery of the island is built of hard, solid limestone (primarily made of reef coral, as tectonic forces raised Curaçao from the sea); the interior is covered by soft and crumbly volcanic rock. Consequently, Curaçao features many large and strategic harbors, for narrow piercings of the hard limestone, easily defended by forts (or even, in early times, by heavy chains stretched from shore to nearby shore), open into ample basins eroded from the soft volcanics. The discovery of oil in nearby Venezuela established Curaçao as a safe place (on a politically stable Dutch island with magnificent harbors) for refining and transshipment. But think of the anomalous mixture, given the island's other economic staple: tourism. Visitors can easily smell the contrast, as the easterly trade winds blow the effluvia from refineries along the Schottegat over the fancy new hotels of Piscadera Baai.

The people of Curaçao form a grand polyglot as well, recording the realities and evils of such a Caribbean mixing point. The Caucasian component mainly derives from Dutch officials and businessmen, Spanish and Portuguese planters, and Jewish merchants. The Jewish community of Curaçao, the oldest in our hemisphere, began in the seventeenth century, when the Portuguese inquisition reached Brazil and expelled a vigorous community of Sephardic Jews, who then fled to havens under liberal Dutch control. Some went to New York (then Dutch New Amsterdam) to become the first Jews in the future United States, but most went to nearby Curaçao. Congregation Mikve Israel still worships in an elegant synagogue built in 1732, the oldest in continuous use in our hemisphere. (Curaçao Jews helped to establish the oldest American congregation, the Touro synagogue of Newport, Rhode Island, in the 1760s.) I felt privileged, and more than a little awestruck, to attend the Friday night service and to think that people of my heritage have been saying the same prayers in the same spot for more than 250 years within this New World of constant change.

The larger African component reached Curaçao involuntarily as chattel in the brutal system of plantation slavery. From this great and disparate mixture of people, a local language emerged, a creole called Papiamentu, spoken only by the few hundred thousand people of Curaçao and the neighboring islands of Aruba and Bonaire In this tongue, *papiamentu* means "speaking"—so the language's name recalls the common practice of cultures who choose as a designation for themselves, the native word for "people" in general. Several features of this fascinating language provide the first of my two examples from Curaçao for the fallacy of misequating less complex with primitive or historically prior.

Plantation owners, in part for reasons o availability, but also as a conscious strategy for preventing a solidarity that migh lead to insurrection, built their retinue o slaves from people of different linguisti backgrounds, so that no secret system o communication could emerge in an "un



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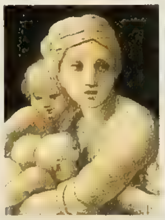

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known" native language. These slaves heard no common tongue but the language of their owners and overseers. They consequently built new languages upon this European base, but influenced by African sources and imbued with features of syntax derived more from universals of human grammar (asserting themselves in this caldron of invention) than from any immediate historical background of the inventors. These languages, which have arisen all over the world during the past 500 years, are called creoles. Derek Bickerton, a specialist on creoles (especially the Hawaiian version, which emerged so quickly after expansion of the sugar industry led to imports of workers from such varied places as China, Japan, Korea, Portugal, and the Philippines), wrote in his celebrated book *Roots of Language* (I also used his companion volume, *Language and Species*, as a source for this essay):

> Creole languages arose as a direct result of European colonial expansion. Between 1500 and 1900, there came into existence. . . small, autocratic, rigidly stratified societies, most engaged in monoculture (usually of sugar), which consisted of a ruling minority from some European nation and a large mass of (mainly non-European) laborers, drawn in most cases from many different language groups. . . . It is generally assumed that speakers of different languages at first evolved some form of auxiliary contact-language, native to none of them (known as a *pidgin*), and that this language, suitably expanded, eventually became the native (or *creole*) language of the community which exists today. These creoles were in most cases different enough from any of the languages of the original contact situation to be considered "new" languages.

In *Language and Species*, Bickerton defines the difference between an original pidgin and subsequent creole. "The gulf between a pidgin and its associated creole, in terms of formal structure, is immense. A pidgin. . . is structureless, whereas a creole exhibits the same type of structure as any other natural human language."

I became fascinated with Papiamentu when I first visited Curaçao and have tried to learn something of its structure (my thanks to many local people, and especially to E. R. Goilo's *Papiamentu Textbook*, the source of most following observations). Papiamentu's base is Spanish and Portuguese, with a strong admixture of Dutch, already quite an amalgamation of Romance and Germanic sources, as seen in such phrases as *Danki Dios* ("Thank God," with Germanic gratitude to a Romance deity).

Beyond these overt amalgamations, the most obvious and distinctive feature of Papiamentu lies in the stripped-down logic of its grammar and syntax. For one who has struggled so many years with the complex cases, conjugations, declensions, pluralizings, and genderings of nouns and verbs in European languages, the simplified, bare-bones structure of Papiamentu provides a distinct pleasure. The stems of verbs, for example, never change their form, either in different tenses or agreements. *Bai* is "going," in the infinitive, the imperative, in the past, present, or future, and whether the motion involves you, we, I, or they. Past and future tenses just modify this universal form with an adverb. The future takes *lo*, from a Portuguese word meaning "later on"—*lo mi bai* (I shall go) literally means "later on I go." The past definite takes *a*. Goilo traces this form to a grammatical holdover from the Spanish auxiliary *ha* of the past tense, but Bickerton argues that, as for the future tense, *a* is an adverb appended to the universal form—from the Portuguese *ja* for "already," so that *mi a bai* (I went) literally means "I already go." Interestingly, the one major exception to the rule of no change for the verb stem lies in the infrequently used gerund, where the Spanish *ando* and *endo* terminations are retained (*lesando* for "reading" or *sabiendo* for "knowing"). Even more interestingly, and showing the vestigial power retained by grammatical structure of a source, the few verbs of Dutch origin do not take this Spanish gerund and have no distinctive ending in this form, but do—and uniquely—alter the verb's stem in the past tense by adding the Dutch *ge* (*skop* is "to kick," but a former kick is *geskop*). What a fascinating mixture of novel logical simplicity and past historical distinctiveness.

Nouns have neither gender nor plural forms. *Buki* is either one or a hundred books. But if the needed distinction can't be drawn from context, you add *nan* (the personal pronoun for "they") to designate a plural. Thus, *e buki* is a book, and *dies buki* is ten books—but the books can be *e bukinan* (literally "the book they"). Sometimes the logic is truly compelling. Papiamentu has no word for son or daughter, but *yiu* is a child of the family (while *mucha* is a child in general)—so *yiu homber* (child man) is your son, and *yiu muhé* (child woman) is your daughter. Similarly, *ruman* is a sibling, and *ruman homber*, your brother, with *ruman muhé*, your sister.

In the past, constrained by stories of progress and a sociopolitical legacy of racism, Western scholars tended to view non-Western languages of nonliterate people as primitive stages (or degenerated reversions) of an evolutionary sequence leading to modern Indo-European tongues. Consider, for example, a standard nineteenth-century work inspired by the Darwinian revolution, William Dwight Whitney's *Life and Growth of Language*, first published in 1875. (Whitney was a professor of Sanskrit at Yale; even the title of his work proclaims the new developmental paradigm, with overt analogy to the progressive and programmed growth of children.) The sociopolitical bias is apparent in his ranking of modern "primitive" languages as intermediate between a conjectured first human tongue and the

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maximal modern complexity of, say, his own English:

> If we hold him [primitive man] to have gradually developed them [the elements of civilization] out of scanty beginnings. . . there is no reason why we should not hold the same view in respect to language. . . . Even in existing languages the differences of degree are great, as in existing stages of culture in general. An infinity of things can be said in English which cannot be said in Fijian or Hottentot; a vast deal, doubtless, can be said in Fijian or Hottentot which could not be said in the first human languages.

But consider also, again in Whitney's words, the more abstract, and largely literary or storytelling, biases for a slow succession of upward steps ("That the process was a slow one, all our knowledge of the history of later speech gives us reason to believe"), and for causal continuity in general ("No account of the origin of language is scientific which does not join directly on to the later history of language without a break, being of one piece with that history").

Given this legacy, it is scarcely surprising that linguists formerly viewed creoles either with contempt ("Despised and neglected for centuries by mainstream linguists as the degenerate products of illiterate nonwhites," as the jacket of Bickerton's *Roots of Language* notes) or with paternalistic interest as a primitive lingo that might expose the evolutionary roots of speech ("those [theories] which sought to derive creoles from the babyish imitations of Europeans' condescending simplifications").

But once we drop these biases and rephrase our questions, we can conceptualize creoles in a new light—not as something simple and prior, a primitive stage of a progressive sequence, but as something unique that might give us insight into the structural nature of language in general. I do not know whether Bickerton's theory for the origin of creoles is correct (and I recognize that his opinions are controversial among linguistic scholars), but his hypothesis does illustrate the important principle that less overtly complex can connote difference with a general message, rather than primitivity to ennoble our own contemporary estate under our storytelling biases.

Pidgins, according to Bickerton, are rough and ready accommodations to necessary communication and have little linguistic structure, while the creoles that derive from them develop all the formal complexity of any true human language (without all the overt frills of conjugation, declension, and so on). So where do creoles come from, especially since they often arise so quickly, usually in a single generation? (This surprising claim for maximal rapidity is well documented, particularly in Hawaii, where polyglot immigration, and its resulting pidgin, only began in 1876, when revision of U. S. tariff laws permitted free importation of Hawaiian sugar, while creolization occurred between 1910 and 1920.)

Bickerton, in short, argues that creoles are largely created by children as they hear the surrounding pidgin and enrich this base by grafting it onto the universal grammar that, according to Noam Chomsky's generative theory, all human beings inherit as a product of the evolutionary development of our brains. If Bickerton is correct, then creoles—as known, traceable, novel languages, replete with full structure but often stripped to the bare bones of universality—provide our best possible evidence for both the existence and the nature of this most precious and defining of human universals, the core for any meaningful concept of human nature. If children create creoles in one pass, and if their parents mainly speak the unstructured pidgin, then the formal properties of language must emerge from within as shared properties of all people. Out of the mouths of babes . . . . Bickerton writes in *Language and Species*:

> What happened in Hawaii was a jump from protolanguage to language in a single generation. Moreover, the grammar of the language that resulted bore the closest resemblance not to grammars of the languages of Hawaii's immigrants; nor to that of Hawaiian, the indigenous language; nor to that of English, the politically dominant language; but rather to the grammars of other creole languages that had come into existence in other parts of the world. This fact argues that creole languages form an unusually direct expression of a species-specific biological characteristic, a capacity to re-create language in the absence of any specific model from which the properties of language could be 'learned' in the ways we normally learn things.

Bickerton then reminds us that we could lose this precious insight if, by hewing too closely to a politically correct notion that "all languages are equal" (in complexity or vocabulary), we neglected the genuine way in which creoles are simpler. Less complex need not connote primitive in a pejorative sense; less complex can also mean "stripped to bare essentials" (a Japanese house versus a high Victorian cottage), so that the universal properties of construction emerge for all to see. All human languages, including all creoles, possess the entire complexity of universal

grammar, but some languages have more bric-a-brac, more gewgaws, more tchotchkes than others—and the "cleaner" creoles may therefore make the underlying universals more visible. "Creoles," Bickerton writes, "far from being 'primitive' in anything but the sense of 'primary,' give us access to the essential bedrock on which our humanity is founded."

As I restudied Papiamentu during my recent visit to Curaçao, and as I developed my thoughts about the error of storytelling that automatically equates less complex with prior or primitive, I realized that Curaçao could provide me with two examples—one from the local language, and one (I recognized with some embarrassment) from my own studies of the local land snails. I am proud of the work I did in Curaçao, but I now realize that I undertook my investigations for the wrong reason. I went to Curaçao because I thought that comprehension of a simple system would unlock the greater complexities of other West Indian islands. I found, on Curaçao, many things of interest in themselves, and I did resolve an old debate in a way that satisfied me deeply and brought rigorous sense to prior confusion. But I never discovered a key to the greater complexity elsewhere—and I now attribute such a hope to the wiles of Scheherazade, rather than the messages of nature.

The landsnail *Cerion* lives throughout the northern West Indies, often in fantastic variety. Hundreds of species have been named in Cuba and the Bahamas (although only a small percentage are valid). But *Cerion*'s geographic outliers tend to house restricted diversity: only one species at the northern limit of the Florida keys (*C. incanum*) and only one at the eastern edge of the Virgin Islands (*C. striatellum*). The three islands of Aruba, Bonaire, and Curaçao form a distant and isolated southern limit, and also feature but a single species, *C. uva*.

As the Dutch were early colonizers and assiduous collectors, *C. uva* is the so-called type (first designated species) of the entire genus, and the name, given by Linnaeus himself, could not have had a more honored source. Consequently, *C. uva* has been long known and much studied. Two major twentieth-century investigations, based on exhaustive collections on all three islands, had reached opposite conclusions. In 1924, the American zoologist H. B. Baker argued, from rudimentary statistical analysis grafted onto the subtle expertise of sustained, if subjective, observation, that populations on the three islands

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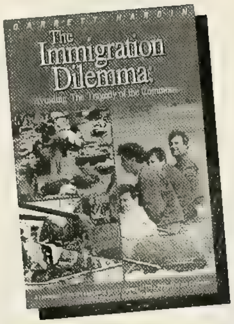

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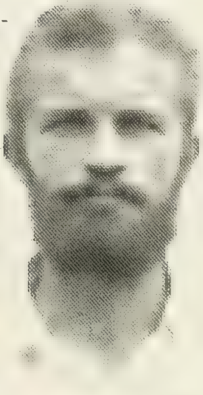

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could be recognized by minor but consistent differences in shell form. He also claimed that shells from western and eastern Curaçao differed in significant ways (Curaçao is a dumbbell-shaped island that would have been divided into two separate parts during past times of higher sea level). But in 1940, the Dutch zoologist P. W. Hummelinck reached an opposite conclusion based on measurements of hundreds of samples, and his student W. de Vries then verified these results in 1974 with an even more comprehensive study. Hummelinck and de Vries found no consistent differences among islands or regions, but great amounts of local variation tied to immediate conditions of wind, sun, rainfall, and substrate.

When I began my work in the late 1960s, tools had just been invented, thanks to that greatest of modern midwives, the computer, for more adequate statistical analysis based on simultaneous consideration of large suites of measurements for each specimen (a family of techniques known as multivariate analysis). Baker, Hummelinck, and de Vries, through force of habit and limits of technology, had treated their variables one by one or at most in pairs (bivariate analysis). Since a shell is an integrated structure with a multiplicity of measurable parts, I reasoned that multivariate analysis might resolve the debate between sensible, regional differentiation (Baker) and crazy quilt, local variation without general pattern (Hummelinck and de Vries).

Again, I visited all three islands and collected hundreds of samples. I measured (or, I must confess, paid a very careful assistant to measure) nineteen variables on twenty snails from each of 135 samples—for a total of more than 50,000 measurements, all then submitted to multivariate analysis of various types (my best technical paper on the subject appeared in *Systematic Zoology*, 1984). I was able to resolve the debate in an interesting way, thanks to the power of the new statistical techniques. Both sides had seen part of a fascinating totality. I could discern the large-scale variation—exactly as Baker had specified—within four areas of Aruba, Bonaire, western and eastern Curaçao. But I also found the basis for the smaller-scale variation within regions, linked to immediate environments, that Hummelinck and de Vries had identified.

Interestingly, these two components of variation could be separated on orthogonal axes (orthogonal means "at right angles," and orthogonal axes are both literally and mathematically independent of each other). Nearly all diversity within this highly varied species could be captured by two independent factors, each attributable to a different biological source, and each identified by a set of shell features recording a pattern of growth through life. I took pride in discovering such an elegantly simple and sensible scheme; I do not think that I have ever been so satisfied with an empirical study, so pleased to extract an underlying pattern from overt complexity that had stymied all prior researchers.

But my study was an utter failure in terms of my original intent. I had gone to Curaçao because I believed that one had to grasp the simple version before tackling the maximally complex manifestation. I went to Curaçao because I wanted to resolve the riotous diversity of *Cerion* in the Bahamas, where hundreds of species have been named. I saw Curaçao as a baby Bahamas. If I could resolve the variation on one island with one species, then surely I would know how to handle a hundred species on a score of islands.

Well, I think I did resolve Curaçao in my intended terms. But this effort hardly aided my Bahamian quest at all. Curaçao is not an embryonic Nassau. Variation within a species doesn't tell you how to treat interactions between species; the phenomena are disparate and exist at different scales. The contrast between me and my neighbor doesn't explain, by simple extension, the gap between me and a chimpanzee. Recent creoles are not baby versions of old and established languages; variation within *C. uva* is not a model fo interaction among several *Cerion* specie in larger regions. Causal continuity doe not unite all levels; the small does not always aggregate smoothly into the large But the small may be interesting in itsel and may teach us much about our world i general. Papiamentu and other creole may lay bare the universals of human language, and *C. uva* may permit us to teas apart the sources of evolutionary variatio within stable species.

Conventional stories about progressiv complexity and causal continuity led earlier linguists to misinterpret (or to ignore creole tongues, and led me to study *C. uv* for the wrong reason. But the solution t these errors does not lie in avoiding stories, for we do not have this option, give our essence. We must, instead, becom more aware of the stories that underlie ou methods and choices of topics for research, and we must learn to recognize th constraints and prejudices that any partic lar story must specify. We should, above ll, enlarge our range of potential stories, or a choice among a thousand and one ights provides so much more scope than Cinderella (or another progressive tale of ags to riches) told every night.

I made my recent visit to Curaçao to atend a conference held to honor the sevenieth birthday of mathematician Benoit Mandelbrot, the inventor of fractal geomtry. Ironically, in the light of my two tales bout mistaken effort in Curaçao, fractals ell a different story that might have proided an exit from the trap of equating mall with simple or primitive. Fractal urves are self-similar—that is, invariant across scales. In the paradigm for a natural ractal, the coastline of North America has io absolutely ascertainable length—for vhat you measure depends upon the scale, ind all scales may show the same basic orm. If I try to measure around every sand grain, the length will be effectively infiite. If I measure only around the approriate wiggles at a scale that depicts Maine o Florida on a piece of paper one or two eet long, then the total length may be exactly the same as a similarly sized map of Acadia National Park measured around each promontory, or a chart of a few feet on one of Acadia's beaches measured around each pebble. In such a fractal world, no scale has any special standing as nigher or lower. The beach is not simpler than the whole coastline, and the beach does not build the coastline by degrees.

I began with a famous line from the eighth psalm (and fleetingly quoted another bit in noting the power of children to create creoles). I should end by citing the lead-in to my first statement: "When I consider thy heavens, the work of thy fingers, the moon and the stars, which thou hast ordained, What is man, that thou art mindful of him?" It is scarcely my place to criticize good King David, for he did slay the giant, and he did pay grievously for dubious actions in losing his friend Jonathan and his son Absalom. But isn't David falling into the same trap by wondering why God should bother with little humanity when he made the stars and all the heavens? For if people are just one level in a predominantly fractal universe, then we are like the galaxies—but the amoeba that we swallowed in that last glass of water and the mites crawling on our eyebrows are also like us.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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Goldilocks had it easy

by Roger L. Welsch

Folks in my part of the country, the Great Plains, take enormous pride in badmouthing the weather. The idea, I guess, is that the weather is so miserable out here that it takes a special breed of human being to deal with it. Tornadoes, hail, blizzards, drouth, floods . . . there's no shortage of harsh weather to comment on. The largest hailstone recorded in Nebraska had a circumference of seventeen inches and weighed a pound and a half—about the size and weight of an artillery shell, with about the same lethal capabilities. The strongest wind velocity remains unclocked because no instrument can withstand the force.

One sees long faces not when the weather is its usual, miserable self but when it's just fine! No Plains farmer would see the point of saying, "Nice weather, huh?" Instead one says, sporting a full grin, "Hot enough for you?" when it is 112°F in the shade. Or (as one wades through four-foot drifts), "Think it'll snow?" You'll be informed it's so hot that popcorn pops on the stalk, so cold that folks go to church just to hear about Hell, so windy that one day the wind stopped and everyone fell down.

We don't claim the Plains are hotter or colder than every other region. Minnesota is free to boast that the Minneapolis snow removal program has a special name, July. Florida can brag about those times it's so hot, fishermen pull their catch from the sea already fully steamed. But few places are both hotter *and* colder than the Plains. Consider North Dakota's remarkable recorded high of 121°F and equally unlikely low of –60°, for an absolute range of 181 degrees. That spread exceeds by one degree the difference between freezing (32°) and boiling (212°).

What's even more remarkable to my mind is that the low was recorded on February 15, 1936, and the high on July 6 . . . 1936. Imagine being a new immigrant to the northern Plains, not knowing quite what to expect from the geography, and getting that initiation within six months. You can understand why, in North Dakota, you can hear both how it was so cold that two cottontails were seen pushing a jack rabbit, trying to get him started, and how it was so hot that cottonwood trees were spotted following a dog.

Hot is hot and cold is cold, but much of the pain—and humor—lies in the contrasts. "The temperature dropped so fast at my place yesterday, the pond froze and the ice was still *warm*," or "The temperature dropped so fast, it bent the nail my thermometer was hanging on." Small wonder that the Liars Olympics of the National Liars Hall of Fame, Dannebrog, Nebraska, happens where it does.

Meteorologists commonly recite figures for high and low temperature or rainfall, but the contrasts and dynamics are harder to quantify. Consider how Nebraskans suffered during the summer of 1931, when they experienced twenty-two days in a row over 100°F. Or how our great blizzard of January 12, 1888, snuck up on a day that started out so mildly that women were hanging laundry on the line, men were picking late corn, and children were setting out for school lightly dressed in anticipation of an early spring.

In a recent weather report, I learned that two Nebraska towns, located about seventy-five miles apart, had a temperature difference of forty degrees, a gradient of one degree every two miles. But experience tells me that you don't really have to travel at all to go from the shivers to the sweats in a matter of moments. I remember fondly the morning that the University of Nebraska, where I was teaching, was closed because of a severe blizzard with high winds, dense snow, and intense cold. Early that same afternoon I washed my car; before supper I took my small boat to a nearby lake and went sailing.

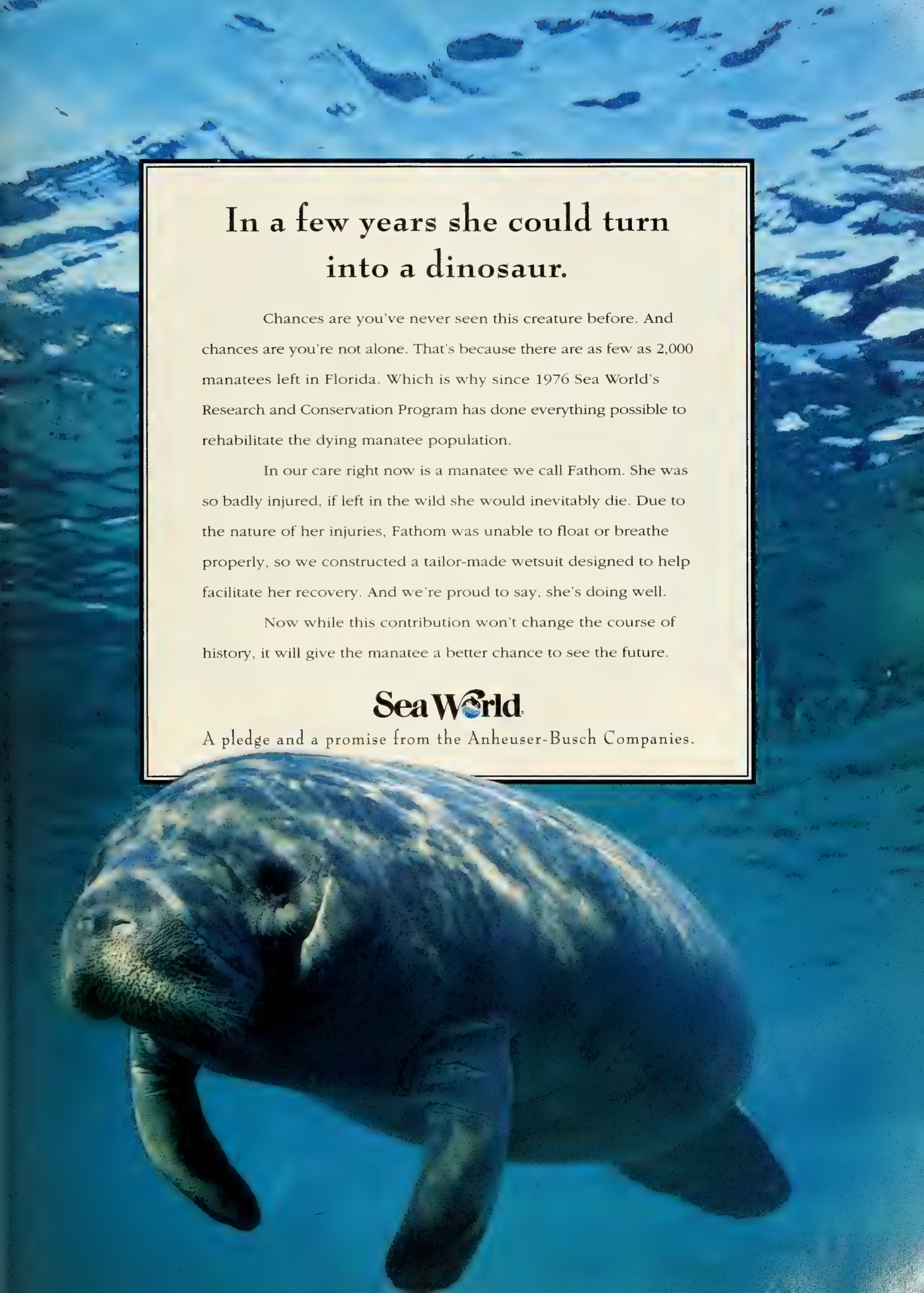
The probable record for a shift in temperature—it's hard to know about such things because until recently records were often kept locally—belongs to Helena, Montana, where it dropped from 63°F to –25°F, a total of eighty-eight degrees, in thirty-four hours between December 14 and 15, 1924. But the most dramatic case I know of happened on January 15, 1943, in the Black Hills of South Dakota. Imagine being in Lead or Spearfish or Rapid City, getting ready to go shopping for groceries or to dress the kids for school, and stepping outside to see what the weather had to offer. At 7:30 in the morning in Spearfish, the temperature was –4°F—brisk, but not unseasonably cold. Problem is, at 7:32 it was 45°—forty-nine degrees warmer. In *two* minutes, the day went from frigid to balmy.

On the same day in Rapid City, not far away, thermometers went crazy. They recorded –5°F at 5:30 in the morning but were showing 54°F by 9:40. An hour later, the temperature was back down to 11°F, only to shoot up to 55°F within ten minutes. At noon it was 10°F, but during the afternoon the temperature climbed to 56°F. By suppertime, the thermometers registered 5°F.

Commenting on the South Dakota phenomenon, *Weatherwise* (October 1961) observed, "With such extremes in short periods of time, one can imagine what great differences must have existed over short distances. It was reported that while the temperature at Lead, South Dakota, was +52°—at Deadwood, only three miles away but at a 600-foot lower elevation, it read –16°. Changes in temperature were so rapid that plate glass windows were cracked in downtown Lead."

And that's the honest truth. (I am grateful to meteorologist Ralph Wall of NTV, Kearney, for supplying many of these statistics. On the other hand, if Ralph is as reliable with statistics as he is with his weather predictions, perhaps the wrong person has been participating in the Liars Olympics.)

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.



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Spinning for Their Supper

American eels mate mysteriously, swim palindromically, and rotate at dizzying speeds

by Gene S. Helfman

Except for the faint, eerie green glow of my liquid-light stick, the narrow tunnel was in total darkness. It was 10:00 P.M. and I was lying fifty feet underwater, on the sandy bottom of a Florida cave called Vortex Springs. Earlier I had placed a dead catfish there as bait for American eels, hoping to observe them feeding in their natural habitat. Such planned observations of eel foraging were part of a larger study of the behavior and life history of this complex and fascinating species.

American eels are the piscine equivalents of snakes, but unlike snakes, eels are truly slimy, often producing copious mucus that makes them difficult to capture. Their slipperiness is enhanced by a general lack of scales. Everything about eels maximizes their stretched appearance and their ability to negotiate tight spots. Their dorsal and anal fins, which lack hard spines, often extend for most of the length of the body, meeting to form a pointed tail. This arrangement allows the eels to swim backward and dig tail-first into soft bottom sediments. The pointed head mirrors the tail in appearance and digging function. Paired pectoral and pelvic fins, which stick out to the side in other fishes, are reduced or even missing in most eels; in addition, the gill cover, so obvious in most fishes, is often reduced to a small hole in eels, again permitting backward and forward movement in tight places, as well as through bottom sediments.

When I first began studying eels' activity cycles, I placed ultrasonic transmitters in their stomachs and chased the signal around the murky waters of a Georgia salt marsh in a small boat. Once I had established that eels were more active at night than during the day, I shifted to diving in the clear waters of Vortex Springs and trying to see the eels for myself.

A juvenile American eel swims in a freshwater spring. At some point, it will return to the Atlantic to spawn.
Doug Stamm; Prophoto

By spending hours underwater in the cave and leaving a videocamera to continuously record the scene when I was absent, I finally learned the eels' nightly pattern. Just after sunset, they left the cave through a vertical chimney to forage for bottom-living invertebrates in the shallows of the spring basin, a better foraging area that received direct sunlight during the day. With the aid of the liquid-light stick and a night-vision scope, I was able to observe eels at close range during their nocturnal forays. They measured from ten inches to two and one-half feet in length, with gray-green or yellow backs and lighter bellies. Smaller animals swam along the basin bottom, stopping periodically to flex their heads downward and poke their snouts into the soft bottom sediments in pursuit of invertebrates, such as worms and insect larvae. Larger animals glided snakelike—or rather eellike—just above the bottom. They were hunting small, sleeping fishes. Their slow, anguilliform movement (a fish's equivalent of serpentine movement) may have minimized the acoustic cues they produced, allowing them to take minnows by surprise and almost literally inhale them. Foraging usually continued throughout the night; ther about fifteen minutes before sunrise, the eels swam back down the chimney anc into the darker recesses of the cave.

The dead catfish I had been watching remained undisturbed that particula night. I went back to the bait an hour before dawn the next day, in hopes that som eel returning from an unsuccessful night' foraging might be tempted by it, but non

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were. I chalked my wasted dives up to bad luck, but they served as a reminder of what an eel fisherman on the Georgia coast had once said to me: "Eels is strange."

No one—biologist or fisherman—has ever seen a reproductively mature adult of any of the fifteen species of freshwater anguillid eels that inhabit the rivers and coastlines of the world's continents and larger islands. In ancient times, Pliny the Elder speculated that lacking sex organs, eels reproduced by rubbing themselves on rocks and that the young developed from scrapings.

In the 1920s, after twenty-five years of poring over data from plankton tows throughout the North Atlantic, Danish fisheries biologist Johannes Schmidt established that larval eels were smaller the closer they were to the Sargasso Sea. Schmidt concluded that both the American and European species of *Anguilla* spawned in this large region of the tropical Atlantic roughly northeast of the Bahamas and Hispaniola. The transparent larvae then floated with ocean currents to North America or Europe.

Recently, biologist James McCleave and his colleagues at the University of Maine have concluded that both species spawn at the same time and place, but they have yet to find out exactly where. Other questions remain: Why do larvae of American eels wind up in the western Atlantic after one year, whereas the larvae of European eels turn up in the eastern Atlantic after three years? And do larvae absorb nutrients directly through the skin since they have no apparent functional digestive tract?

Subadult American eels are also mysterious. Called yellow eels, they spend as many as forty years in freshwater streams, rivers, lakes, and estuaries, eating, growing, and preparing for the final phase that will take them back to their spawning grounds. Males are largely restricted to the coastal sections of streams and rivers in the southeastern United States, while females abound north of Chesapeake Bay and upriver from estuaries. Males also begin to mature more quickly and grow no longer than eighteen inches, whereas females commonly reach twice that length.

In their mature phase, both sexes stop eating and turn silvery bronze as they begin a three- to five-month-long fall and winter migration, presumably back to the Sargasso Sea to spawn and die. Pectoral fins become pointed and, in males, the eyes enlarge, but the functions of these and other changes are unknown.

Some of my own investigations have focused on yellow eel feeding. Even this work has yielded surprises. In testing various baits at Vortex Springs, for example, I noticed that eels usually swam up to bait and sucked it in, a feeding action common to most fishes. At other times, they grabbed the bait and shook it vigorously, tearing off a small piece and swallowing it. Some eels took the bait in their mouths and spun around vigorously and repeatedly on their long axes, until a piece of food broke free. This spinning behavior was what I was trying to document during my "dead catfish" dives at Vortex Springs.

Many predatory fishes have evolved specialized dentition and jaw musculature for feeding. Instead of attempting to swallow their prey whole, predators such as the piranha, bluefish, barracuda, and the African tiger fish can cut or dismember prey, reducing it to swallowable size. Less spectacular and less effective is nibbling, the feeding style of many species such as sunfish and cichlids.

An anguillid eel lacks the ability to nibble. Its teeth are numerous, small, round, and often blunt, with no cutting edges, and its jaw muscles are relatively weak, functioning mainly for grasping and holding. Yet eels are consummate scavengers, and successful scavenging requires an ability to dismember large food items (vultures and crows use strong beaks, and crabs and crayfish have claws).

An eel tears prey apart by grasping and then jerking, pulling, twisting, and spinning. Effective pulling requires an ability to swim backward forcefully. Most fishes can only pull backward weakly by sculling with their pectoral fins. An eel, however, can swim palindromically, which is to say that it can move forward or backward with equal facility. And rather than limiting itself to the forces created only by jaw and head, an eel can employ all of its body mass. When simple pulling or jerking is ineffective, an eel resorts to spinning. (Humans resort to spinning when dealing with objects that won't come apart by simply pulling—disarticulating a chicken leg, for example, or breaking a stick of green or fibrous wood.)

Spinning is a complex adaptation, which I discovered more about while experimenting with eels in aquariums. Size and consistency of foods determined the feeding method. Faced with a large morsel of firm food such as a fresh fish carcass, an eel grasped it, then spun itself around at a rate that would be dizzying to most other vertebrates. I recorded average rotational rates of six spins per second and maximum rates of fourteen spins per second in American eels. To place these numbers in some perspective, Olympic-class ice skaters seldom achieve spin rates exceeding five rotations per second.

A spinning bout may last four seconds and involve twenty-five spins, but how the forces are generated and maintained is a mystery. Videotapes reveal no twisting in the body after the first few spins. All that can be detected is a straight or slightly curved body rotating simultaneously at all points, much like a hot dog on a rotisserie. Internal pumping of body fluids probably generates the force, and the uniquely elastic collagen fibers contained within an eel's skin aid in conserving the energy needed to complete rotations.

More than thirty other vertebrates spin for their supper: crocodiles (watch the final chase scene across the suspension bridge in *Indiana Jones and the Temple of Doom* for an example), moray eels, some deep-sea "cookie cutter" sharks, Asian catfish, tadpoles, and king cobras.

What are the advantages of spinning? An eel, like most fishes, amphibians, and reptiles, is gape limited, meaning it can eat only what it can swallow, and what it can swallow is determined by the width of its mouth, which in American eels seldom exceeds two inches. Many species take advantage of gape limitation in predators by increasing, or seeming to increase, their body size so as to appear too big to swallow. Blowfishes, for example, puff themselves up. The bluegill sunfish erects its dorsal and anal spines, increasing its body depth by about 40 percent. Deceptive increases in body size can be accomplished by erecting skin flaps or body hairs—a tactic of both the Australian frilled lizard and the house cat.

Overcoming gape limitation while scavenging is only part of the function o spin feeding. Spinning is also useful in capturing live prey or gaining access to foods. By spinning, an eel can pull off the exposed neck of a buried clam or rapidly dismember a recently molted blue crab.

In the aquarium, I observed several small eels grab the membranous tissue surrounding the cloaca of a dead female American shad and begin spinning Within minutes, the opening had been enlarged sufficiently to allow the eels to enter into the fish's body cavity and stuf themselves on eggs. A similar scenari probably explains how two eels got insid a large female Atlantic sturgeon tied to Georgia dock a few years ago; the eels de stroyed the ovaries, rendering a fish worth more than a thousand dollars for its caviar into a much less valuable carcass.

Spinning also functions as an escape tactic. Clement J. Walton, of the Maine Department of Resources, watched a mink capture a large eel in the Damariscotta River. The eel began to spin rapidly, rotating the mink with it. Only when the mink stuck out a paw and grabbed on to a rock was it able to drag the eel out of the water and consume it. A spinning eel can also turn a fishing line into a tangled mess.

In terms of expended energy, however, spinning is not as economical as suction and shaking. I have observed an eel in the aquarium feeding on a shrimp by spinning, but after disarticulating and softening it, the eel switched over to shaking and eventually to suction. Over a five-month period, suction-feeding eels maintained their weight, while eels that shook and spun their food lost considerable weight, and eels that fed only by spinning fared the worst. Eels even selected suction food over shake or spin food, and shake food over spin food. Natural selection has apparently favored eels that can distinguish between easy pickings and food that requires considerable effort.

Another significant cost of spinning may be its conspicuousness. An eel spinning at half a dozen rotations per second—white belly flashing periodically, vibrations pulsating through the water with each rotation—may advertise itself to predators. And a spinning eel may be less alert to approaching danger when it is preoccupied with tearing off food and distracted by a swirl of stimuli around its head and lateral line. Indeed, a stroll through any fishing tackle store will document the confidence of the sport fishing industry that eellike shapes and spinning objects are stimulating to predators. We also know that largemouth bass housed in aquariums adjacent to aquariums with eels will try to attack spinning eels more often than they attempt to attack resting eels that are suction feeding.

With so many liabilities associated with spin feeding, why do eels spin in the first place? Normally, an eel spends much of its time swimming and probing the bottom for small invertebrates. Filling its stomach requires not only many small insects or worms but also time—time lost from territorial defense, resting, growth, and avoidance of predators. These losses reduce an eel's ability to accumulate the energy stores necessary for egg or sperm production and the long journey back to the Sargasso Sea. If an eel encounters a large package of energy in the form of a recently dead or moribund fish, it can feed to satiation by spinning for a short period, while also reducing the time it spends searching for food and exposing itself to predators. By spinning, an eel can dismember large or tough prey, gain access to otherwise physically protected parts of potential prey, and escape from enemies.

Much remains unknown about the activities and behavior of American eels and the biology of other eel species—be they river, moray, conger, snipe, tiretrack, snake, worm, rope, rice, glass, or wolf eels, which abound in the world's lakes, rivers, and oceans. An eellike body is obviously an efficient and successful form that creates behavioral options unavailable to other fishes. Understanding these options, and how eels exercise them, is a task that I am more than willing to spend many dead catfish dives unraveling.

Gene Helfman is an associate professor at the Institute of Ecology at the University of Georgia. He is senior author, with B. B. Collette and D. E. Facey of an ichthyology textbook, The Diversity of Fishes, *to be published by Blackwell Science.*

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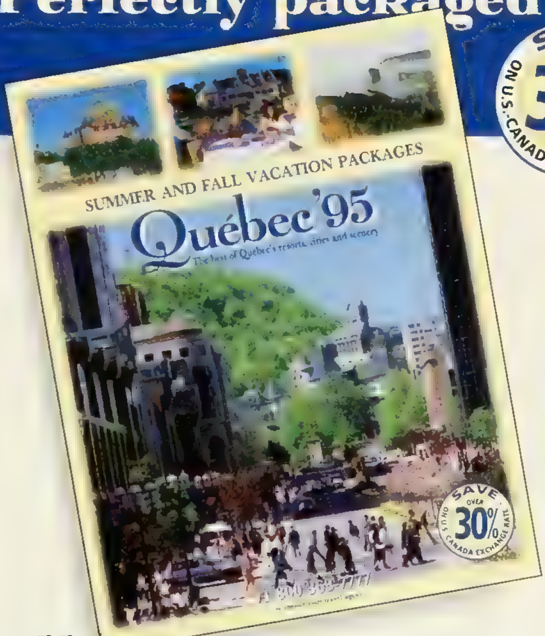
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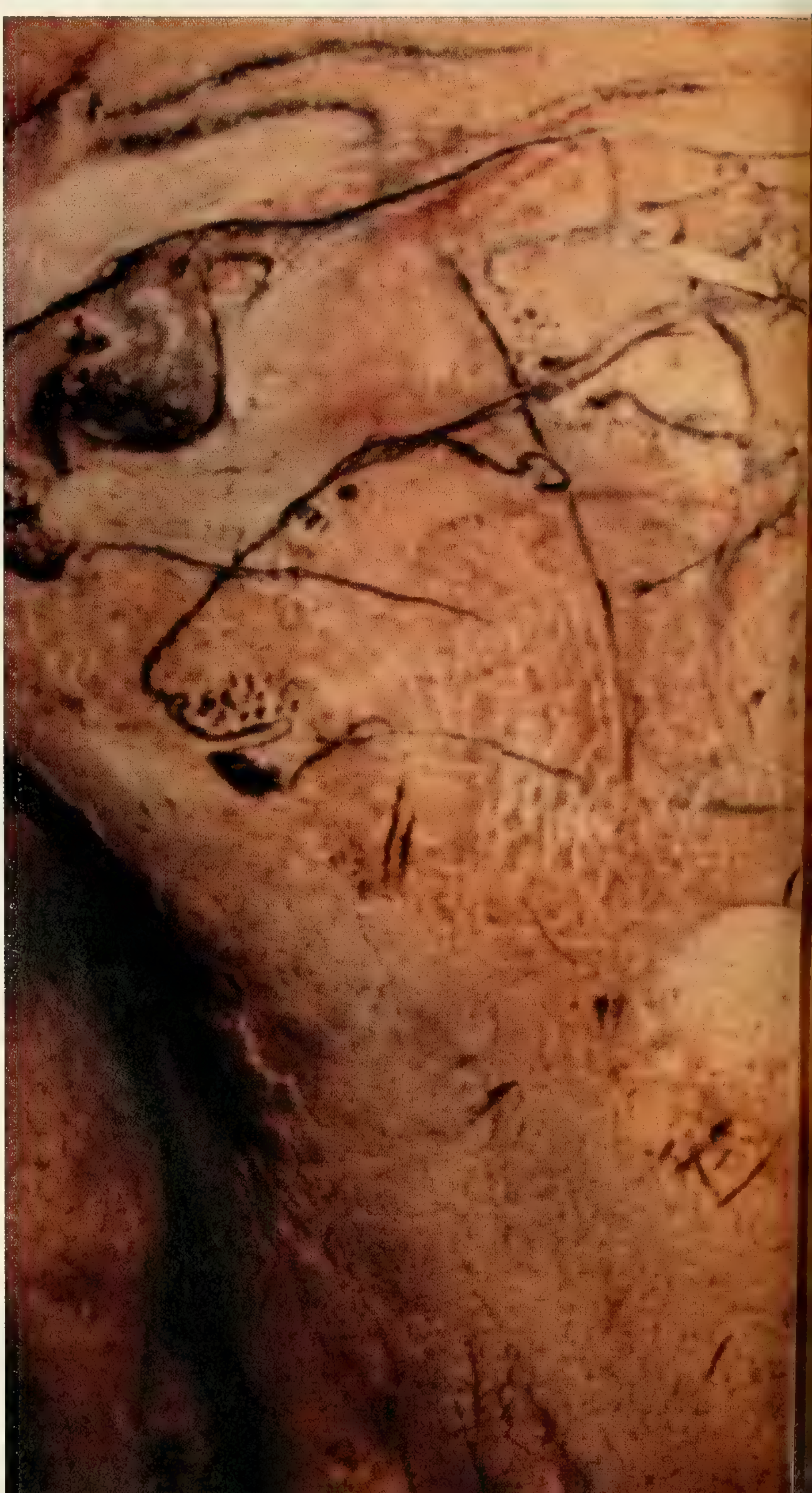
Rhinos and Lions and Bear

An archeologist explores the newly discovered Chauvet Cave



On Thursday, December 29, 1994, I was at my home in Foix, France, preparing for a New Year's celebration. My three children, their spouses, and my seven grandchildren (ranging in age from six months to ten years) were arriving that day and the next for a crowded family weekend. At noon the phone rang. Jean-Pierre Daugas, the regional conservator in charge of archeology for the Rhône-Alpes region, was calling to tell me that there had been a major discovery in the Ardèche Valley in southeast France. A few days before, on Christmas, three men had discovered a big cave with hundreds of paintings and engravings representing lions, rhinos, bears, horses, bison, and even a leopard and a hyena. By chance, they had felt a draft through stone rubble that blocked a small hole at the foot of a cliff in the valley. After moving the stones, they managed to wriggle through a narrow passage into a hitherto unknown painted cave and believed they were the first humans to enter it in 20,000 years.

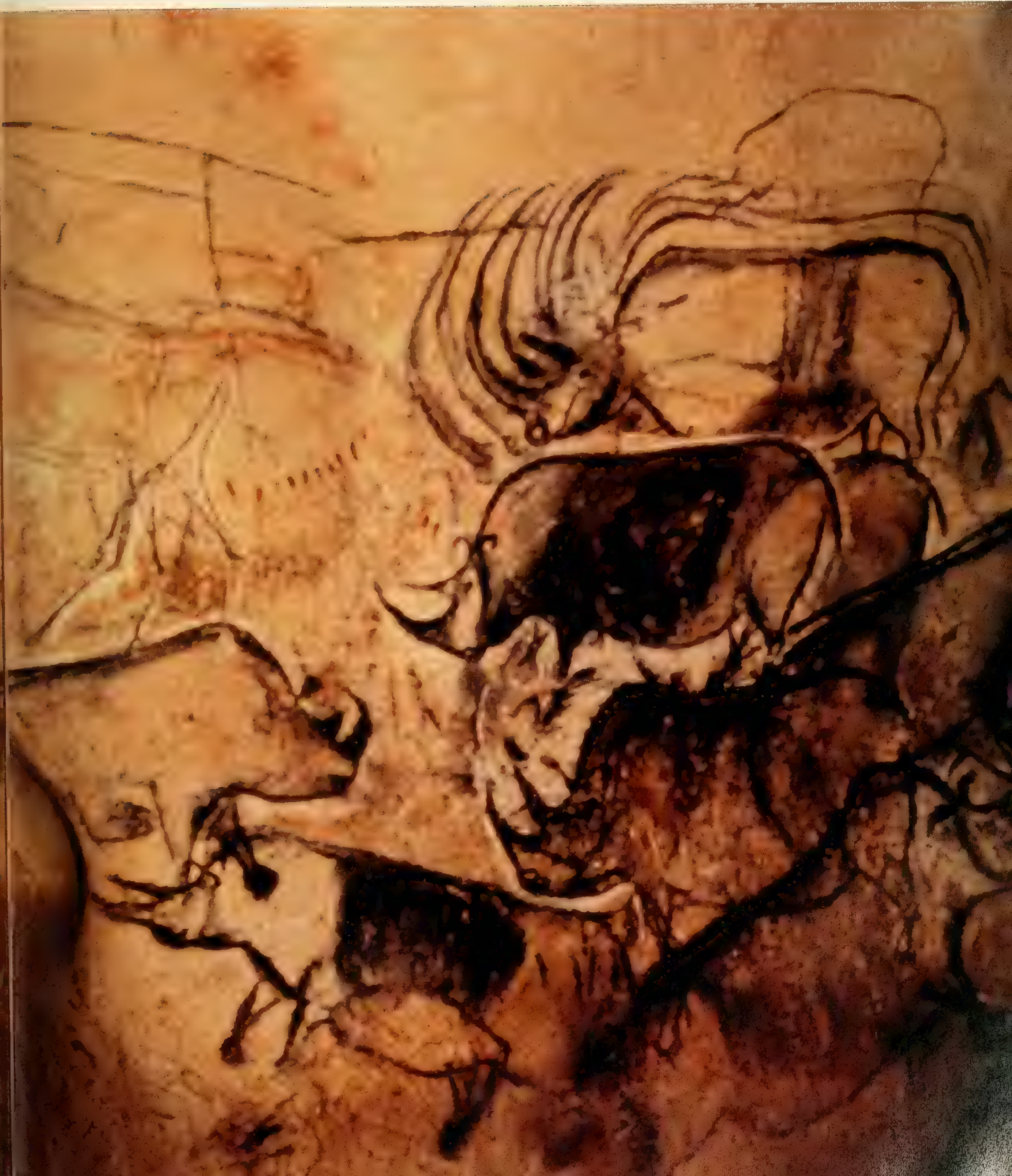
Leopards and hyenas were unknown in Paleolithic cave art, and lions, rhinos, and bears were rare. Situated near the town of Vallon-Pont d'Arc, the cave is in a very touristy area where more than a million visitors, including many cave explorers, roam every summer. Could this be a hoax? Daugas insisted it was not. One of the discoverers, Jean-Marie Chauvet, was well known to him, as he was employed by the Ministry of Culture as a guard at the painted caves in the Ardèche region. He was trustworthy and so were his two companions, Eliette Deschamps and Christian Hillaire, who had discovered several minor painted or engraved caves in the Ardèche and Gard areas during the past ten years. I said I would go the following week. But Daugas pressed me, saying, "This looks extremely important and I really wish you could come right away." Reluctantly, I decided to disappoint my family and go check out the cave. The same afternoon I packed my cave overalls, miner's lamp, helmet, camera, and flashlight and drove to Vallon-Pont d'Arc, about 250 miles away.

Oh, My!)

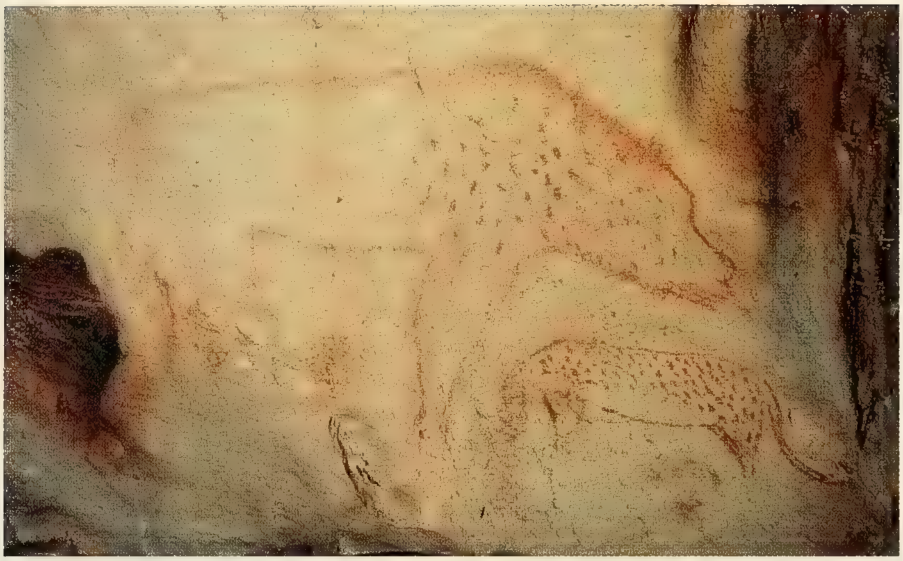
Text and photographs by Jean Clottes

Drawings of rhinos, lions, and reindeer are among hundreds of animal images found five months ago by spelunkers in France's Ardèche Valley.

All photographs courtesy of the French Ministry of Culture; SYGMA



Although its head is bearlike, the large, spotted red figure may represent a hyena. The smaller image beneath it is unmistakably a leopard.



The next morning, Daugas, along with one of his colleagues and the three cave explorers, met me at the hotel and we set off for the cave. I felt duty bound to tell them that I would have to question everything because my first concern was to ascertain whether such a spectacular discovery could be a fake. They just laughed and said they were not worried.

It was a bleak winter day, and heavy fog shrouded the normally beautiful countryside. We climbed briskly through thick woods to the foot of a cliff. After following along its base for a while and passing several small caves, we reached an unpromising cavity, several feet wide, which my guides said was our entry point. We scrambled down the sloping hole for about thirty feet to a heap of loose rocks that covered a much narrower opening. It was here that the discoverers had first noticed the air current rising. When they first came upon this much deeper hole, they had to spend an entire day removing rocks that had been blocking it. Before leaving the site, however, they had stacked enough rocks over the entrance to hide it again. Now they removed this small pile and crawled into the cave. Then it was my turn. The seven-foot passage was so narrow that I had to strip down to my overalls before attempting to go through. After a difficult ten minutes, getting stuck repeatedly and creeping forward only while exhaling, I emerged on the other side, where I descended a thirty-foot hanging ladder they had left there. At the bottom I found myself inside a vast chamber.

Obviously, the Paleolithic artists had not used the access we had been through, which opened into the ceiling of the cave. Hours later, we found the cave's original entrance some hundreds of feet on the other side of the chamber. It had long been blocked by a huge pile of rocky debris, perhaps soon after the cave had been visited by humans. This blocked entrance will remain as it is, so as not to change the climatic conditions inside the cavern.

My first impression of the cave was that it was vast, pristine, and beautiful. Stalactites and stalagmites sparkled everywhere under our lights. The ground seemed untrodden, and on the other side of the chamber I could distinguish a first panel of red dots. We went over to it, and I examined it closely. The dots were large (two and a half to three inches in diameter) and numerous, resembling those in the cave of Pech-Merle in Quercy. The ancient paint had long ago penetrated into the wall, and a thin veil of calcite covered a few dots. They were undoubtedly authentic. We followed Jean-Marie Chauvet closely, stepping where he told us in order not to destroy any traces or even dirty the ground. He carefully unrolled long slips of black plastic in front of us, choosing a path where the ground was solid rock or covered with thick calcite, and skirting the soft places where prints might be preserved.

In the first chambers, most of the art consisted of red figures. Next to a few hand stencils and red dots, we saw only one black horse, half-hidden under an old layer of calcite. In a smaller gallery, the outlined head of a red deer was followed by three cave bear images and one of a horse. In creating one of the bears, the prehistoric artist had utilized the natural relief of the wall as a three-dimensional shoulder for the animal. Elsewhere, three rhinos followed one another in a long frieze. As is always the case in Paleolithic painted caves, there were many geometric signs: several panels of dots, similar to the one we had first seen; a semicircle of much smaller dots; and a few cryptic drawings. Two of these strange geometrics resembled birds or bats, while others were reminiscent of insects with multiple legs.

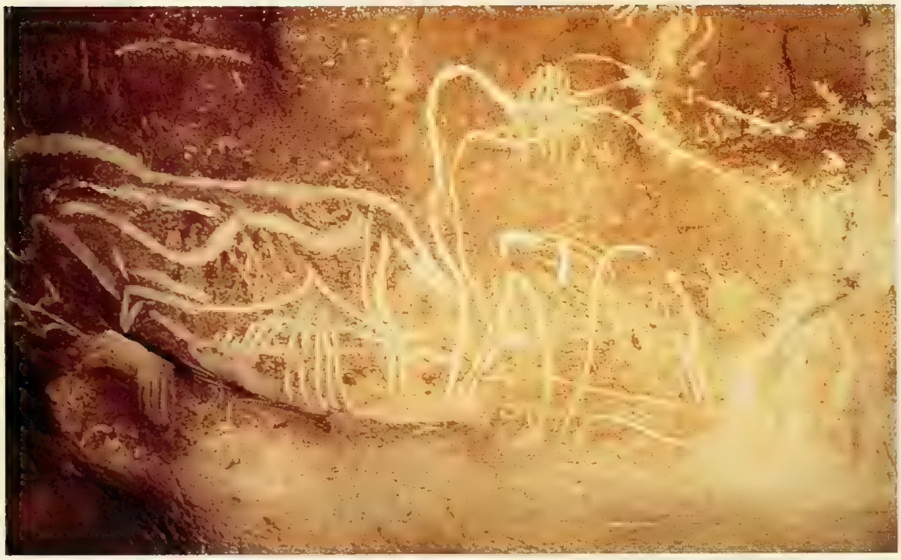
The recognizable creatures painted in red included several rhinos, bears, and lions, at least one ibex, four mammoths, one bovid, and two other animals close to each other. One was indisputably a leopard, recognizable by its spots and its tail, which was devoid of the tuft all lions possess. The other one was bigger. At first, I identified it as a bear, but I was bothered by its spindly legs, its shortened hindquarters, and the spots on the front part of the body. I then let myself be persuaded that it might indeed be a hyena, as Chauvet had said in the first place. If it really was a hyena, it would be the first depiction of that animal in Paleolithic art, just as the leopard is the first known example of its kind. However, I am far from certain what it is; it still could be a bear.

After a low passage full of stalactites, we reached other chambers. In one of them, the ground had collapsed, and a deep crater about thirty feet wide had opened up. Above it, an owl, two mammoths, and a horse had been engraved on an overhang at a time when it was easy to reach. Now the engravings stood about fifteen feet above the bottom of the crater. This was further evidence that no forger could have been at work on the walls.

Farther on, we came to several extensive panels crowded with numerous black figures. These paintings were truly astonishing: on the whole they were well preserved and distinct. Most of the animals were recognizable as to species and sometimes even as to sex or behavior. Contrary to what can be seen in most painted caves, these animal depictions seem to be grouped into compositions. For example, one of the main panels appears to be organized on both sides of a small recess, inside of which a horse, a mammoth, and a rhino have been painted. On the right, there is another, young-looking mammoth, several rhinos, and some bison, followed by a group of fourteen lions with their heads stretching in the direction of other animals. Behind the lions is a solitary rhino. On the other side of the recess is a spectacular series of at least thirteen or fourteen rhinos, some superimposed on the others; most are facing left while two face right. Then there are four big lions, all on the alert and looking to the right. In the middle of the group, one sees a reindeer and at least two series of red spots of various sizes—the smaller ones in a line; the bigger ones in a sort of semicircle.

Could this really be a composition rather than the placing of unrelated animals on the same walls? Already, I thought of what would have to be done to try and find an answer to this question. Analyses of paint constituents might reveal whether all the animals had been done at the same time, with the same paint. All the images would have to be traced carefully and the techniques used by the artists investigated. We could not go up to that panel because the ground in front of it was untrodden and fragile, so we stayed about thirty feet back and examined it from a distance.

Outlines of two mammoths and a horse were engraved on a rock overhang at a time when it was more accessible. The cave floor beneath it has since collapsed.



We could, however, get close to another one, equally complex and beautiful. There, on one wall, animals of different species had also been represented in black, and some of the images had been superimposed on others. Detailed chemical analysis would in time tell us which animals had been done first or last and enable us to establish the different phases in the composition. A first examination showed, for instance, that some small rhinos had been partly covered by four big aurochs, while another rhino was on top of one of the aurochs and four horses' heads were on top of this rhino. Two other male rhinos seemed to be fighting; such a scene is unique in Paleolithic rock art.

While I was gazing at the panel, trying to distinguish the succession of the images and, in particular, looking closely at the splendid heads of the four horses, I was suddenly overcome with emotion. I felt a deep and clear certainty that here was the work of one of the great masters, a Leonardo da Vinci of the Solutrean revealed to us for the first time. It was both humbling and exhilarating. Humbling because of the admiration one could not help but feel for the artist, forever unknown, whose works had spanned the millennia, and because the discovery underlined the immensity of our ignorance. If after more than a century of research such original and important paintings could still come to light, how many had been destroyed or were still unknown in the depths of concealed caves? On the other hand, I was thoroughly exhilarated to be there, one of the fortunate few to first behold such a masterpiece.

After a whole day spent in the cave it was possible to make a preliminary assessment. The authenticity of the paintings and engravings is beyond question. The cave is a major discovery because of the number of animals represented on its walls, their esthetic quality, and their originality. Of course, years of study lie ahead. For now, nothing can be said as to the precise dates for the works of art, the activities of prehistoric people in the cave, the meaning of the paintings, or the choice of panels. That will come later. But the indisputable authenticity makes the Chauvet Cave, as the discoverers want to call it, one of the great archeological finds of the century.

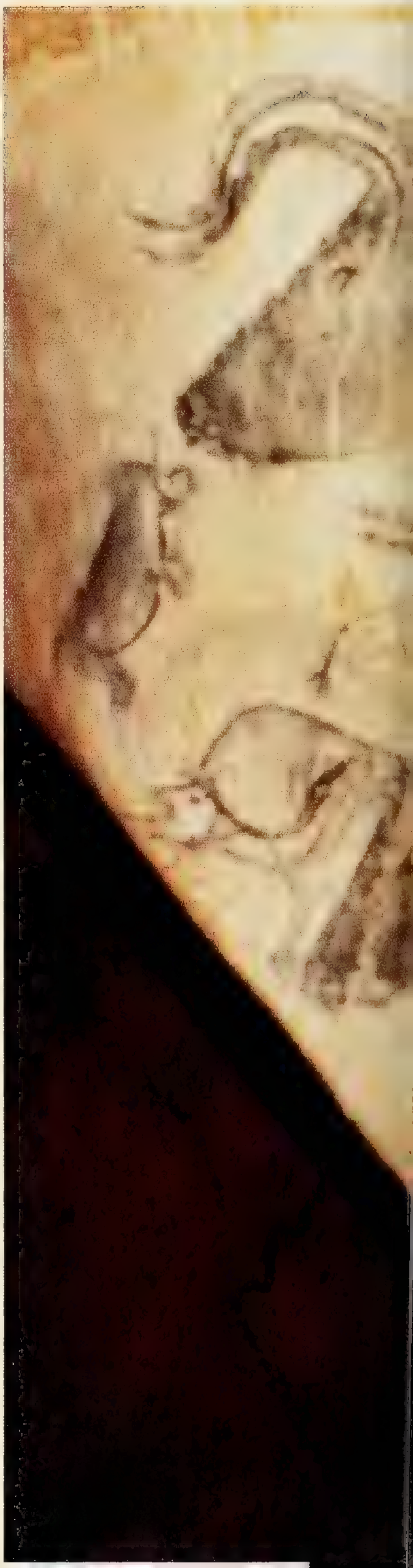
I saw more than 150 animal images that day, and I probably missed many more, as it was impossible to walk to the other side of some chambers in which the ground was littered with cave bear bones and where undisturbed prints could be seen on the surface. Across one of those chambers, we could just make out the outlines of more images, unrecognizable from a distance. Most probably, when the cave is explored in detail, there will be 200 to 300 animal figures and possibly even more. In comparison, among French caves considered among the most important in Paleolithic cave art, 145 animal paintings or engravings have been found in the Cosquer Cave near Marseille (*see* "Neptune's Ice Age Gallery," *Natural History*, April 1993) and 110 in Niaux, in the Ariège.

Most of the animals in the Chauvet Cave are rhinos, lions, and bears, which is very surprising. Generally, those most often represented at the time were horses, bison, aurochs, mammoths, deer, and ibexes. Images of these animals are also present in the cave, but the emphasis on predatory animals that were probably not hunted testifies to a regional difference in the Ardèche culture during that time.

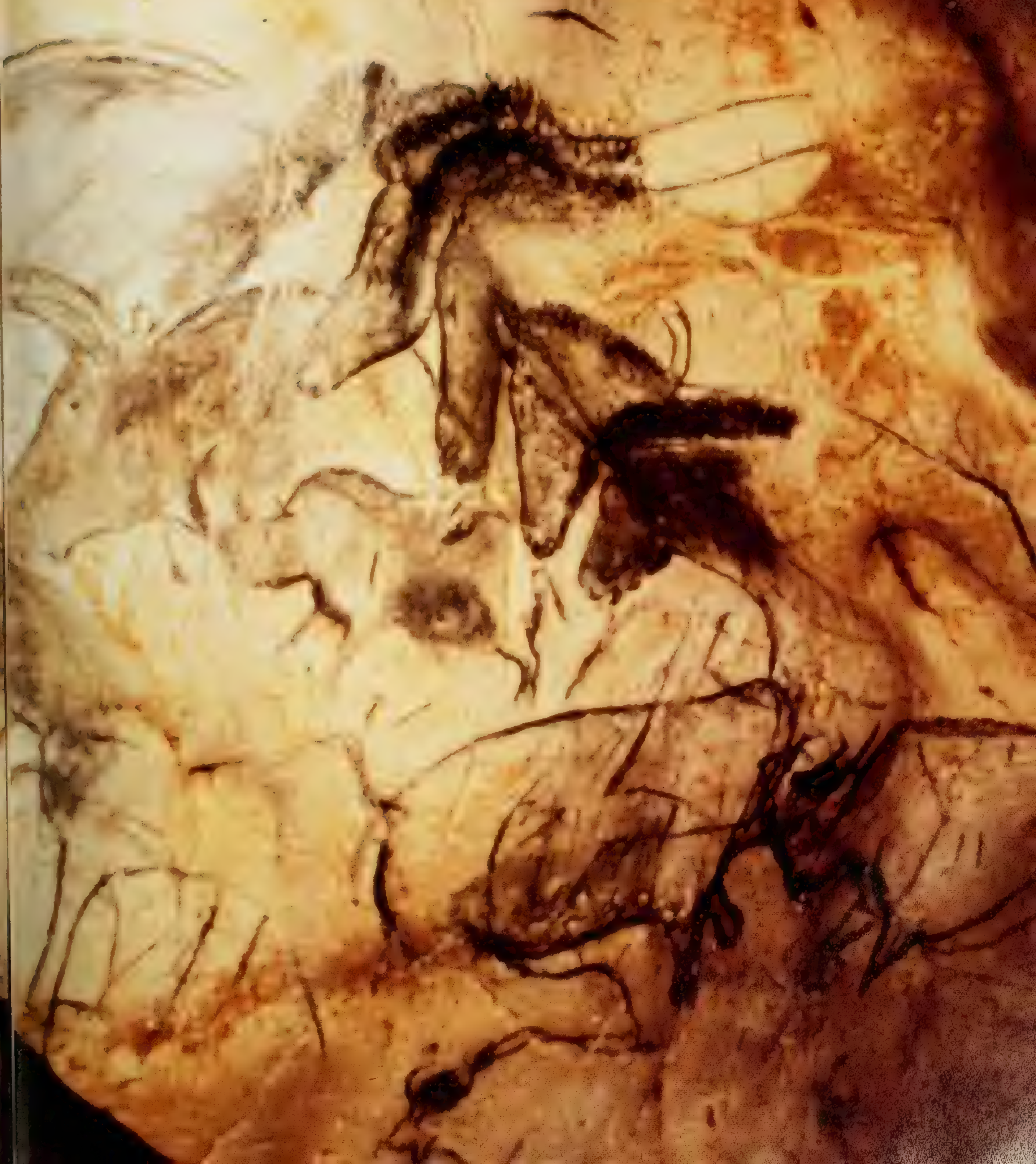
Exact dates for the paintings are still a matter of conjecture. However, some details point to a pre-Magdalenian period—the Solutrean, about 18,000 to 21,000 years ago, which is already represented in the Ardèche caves but is rare elsewhere. The panels of big dots and at least one deer are similar to the ones in Pech-Merle, a cave where stenciled red hands have also been painted and which is generally attributed to the Solutrean. Several bison are pictured with their horns facing front, while their bodies are shown in profile and their heads in three-quarters view. The style reminded me of a similar bison in the recently discovered Cosquer Cave, which is half-submerged in a seacliff on the Mediterranean and has been radiocarbon-dated to about 18,500 years ago. Three animals that appear to be Irish elk—an extinct deer with giant antlers—have been painted in the Chauvet Cave. Those animals appear very rarely in Paleolithic art but happen to be present in several caves dated to the Solutrean or even earlier times, such as Cougnac and Pech-Merle in the Lot region, just south of the Massif Central, and again in the Cosquer Cave. If the Chauvet Cave is indeed Solutrean, which we shall know after radiocarbon analyses and archeological studies have been done, it will be the most important sanctuary ever discovered for that culture. In any case, the Ardèche, and more generally the southeast of France, is no longer a minor area for rock art. It now ranks among the best, along with the Pèrigord, the Pyrenees, and Cantabria.

Finally, the Chauvet Cave stands out because it has been so well preserved. The discoverers were extremely careful to walk where they would cause no damage. In places, the remains of fires can still be seen. Elsewhere, the ancient soil is covered with bear and human prints. Cave bear bones litter the whole cave. It will be necessary to determine whether the bears hibernated in the cave thousands of years before humans came or were present at the same time. An in-depth study of all traces should also tell us whether children went there with the adults and possibly what sorts of activities went on. In one chamber, for example, a cave bear skull has been placed on top of a big block of stone in a very dramatic way. What could this mean? Have any other bear bones been moved? And why? Did the bears go back into the cave after humans had decorated the walls? Many such questions are unanswered for the time being.

In the months and years to come, much research will be carried out in the cave. However, our first priority will have to be its preservation. A discovery such as this is exceptional from many points of view, and exceptional care is therefore in order. We have often regretted that the excavation of such caves as Lascaux and Altamira destroyed their archeological context, either through carelessness or to answer some questions of the time. In future years, our successors will have different theories and models, and they will use different techniques. Nothing should be done to destroy the primary evidence. Strict precautions must be taken against vandalism, and some restrictions placed on research. After preservation, scientific study will be our second priority. Research will take years to complete and must be nondestructive. Our third priority is to respond to the enormous public demand for films, CD-ROMs, and replicas of the images. These will become possible in time, but there is no hurry. After all, what are a few years to wait for a cave that has waited for us for fifteen or twenty millennia! □



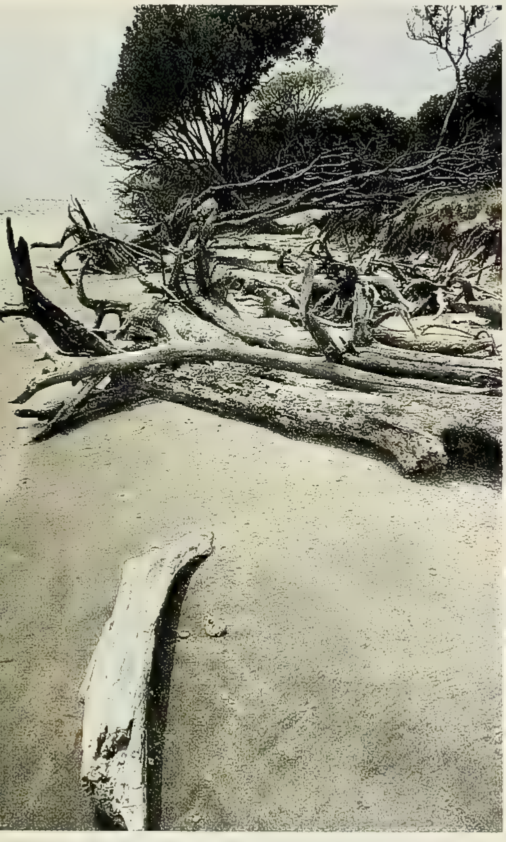
A small image of a rhinoceros is surrounded by large renderings of aurochs, or wild oxen, and Ice Age horses. The scene of battling rhinos, at lower right, is unique in cave art.



Text and photographs by Gary Noel Ross

Butterfly Wrangling in Louisiana

Cajun cowboys and caterpillars share a Gulf Coast habitat



Driftwood lines an eroding chenier, a ridge of ancient beach now surrounded by water and marsh. Opposite page: Prickly pear cactus grows beside a live oak.

More than half of Cameron Parish, in the southwestern corner of Louisiana, consists of open water, and most of the land is a marshy labyrinth. The parish's only patches of solid land are its cheniers; composed of sand, shell, and organic material, they rise one to twelve feet above the surrounding muck. Geologically, cheniers are ancient, dry beach ridges, originally built up near a delta and now separated from other high ground by extensive intervening marshland. Long and narrow, cheniers parallel the coast and exist where a voluminous river has periodically changed its course. The Louisiana cheniers, which are anywhere from several hundred to 2,700 years old, result from the meanderings of the mighty Mississippi. Cheniers are found nowhere else in the United States and in only four or five other places in the world.

Louisiana's cheniers were once all wooded, dominated by live oaks and other water- and salt-tolerant hardwoods such as hackberry and locust. (Coined by early Cajuns, the word *chenier*, pronounced "shin-ear" or "shin-a-ree," means "oak place.") They were biological islands, upland forests afloat in a grassy sea. Until roads were constructed linking the cheniers to higher ground farther north, local folk had only one form of transportation: boat. Today, practically all the lands are privately owned and are used for cattle ranching, which was introduced from eastern Texas decades ago. Over the years, the local people have cut down most of the forest for wood and to create pastures and farmland. Cattle roam along mazelike trails through the pastures and the remaining patches of woodlands, and Cajun-speaking cowboys float the cattle to market on oil-drum rafts.

Because the coast is subsiding and the sea level is rising, the southern faces of several cheniers are currently under assault by the waves of the Gulf of Mexico. Storms originating farther south also funnel through the area. Although erosion is proceeding at an alarming rate, this precarious world is still a haven for an odd collection of plants and animals. Where else can one find, growing within just a few feet of one another, water hyacinths, Louisiana irises, lantana, prickly pear cactus, gigantic live oak trees festooned with Spanish moss, and Spanish bayonet? And where else could a lepidopterist like me have a better adventure?

It began on March 23, 1991, while I was tagging migrant monarch butterflies on a wooded chenier as they arrived from their wintering grounds in Mexico. My attention was diverted by a small, white butterfly flying lazily in the dappled light. I automatically thought "falcate orangetip," but then logic asserted itself. That species, *Anthocharis midea*, normally appears only in early to mid-April and only in upland oak-hickory forests, such as those of central and northern Louisiana. But when I netted the butterfly, I was able to confirm my first impression: it had a falcate, or hooked, tip on each forewing, as well as other identifying characteristics of the species. (A slightly tattered female, it lacked only the distinctive orange wingtips, found in the male.) I concluded it was a rare stray that had traveled from the north or from Texas, to the west.

The event was filed away in my mind until the following year. Then on March 19, 1992, I noticed another lone falcate orangetip in that same enclave of hardwoods. It proved to be a freshly emerged male. By day's end I had counted nine freshly emerged butterflies, five males and four females. And even better, I was able to track a female until she began to lay her eggs. The host plant she chose, appropriate for this species of butterfly, was Pennsylvania bitter cress, a plant with fine leaves and tiny white flowers. An annual, the plant grows only eight to twelve inches high in this hot locale, going to seed earlier than in more temperate areas.

The butterfly usually deposited just one of its conical, orange eggs per plant, on a bud or open flower or at least near the flower head. I noted that the water-loving bitter cress flourished in patches on the northern slopes of the cheniers, in the soggy boundary between the light-colored soil of the chenier proper and the black muck of the marsh. The plants were growing near partly shaded patches of woodland, frequently bordering the branching cattle trails that were etched in the landscape. The most robust plants had actually sprouted in hoof prints.

Concluding that I had discovered an unrecorded breeding site for the falcate orangetip, I spent the next two days combing the region for other colonies. By dusk on March 21, I had mapped four colonies on four different cheniers, a total population of fifty-six butterflies. But the next day was disappointing; I located only a handful of butterflies throughout the four colonies. And the following day, I found none at all. My fifty-six research subjects had disappeared, as if into thin air. And because of heavy thundershowers the previous evening, coupled with poor drainage, three of my four study plots were now under nearly a foot of water. I wondered if I had just witnessed the demise of this newly discovered population.

I awoke early on March 24 and made my way from the motel where I was staying to the nearest plot for another search. Wearing rubber boots, I waded cautiously about, trying not to alarm any of the cattle and keeping an eye out for poisonous water moccasins. I noticed that the bitter cress plants were still evident, although for the most part, only their tips were above the waterline. I crouched to inspect one plant and was gratified to see a tiny orange egg, unmistakably that of the falcate orangetip. I moved on. By day's end I had painstakingly counted sixty-three eggs, usually one per plant, distributed throughout my four study plots.

Apparently, in less than one week, the adults had mated, and the females had deposited their eggs. Their reproductive drives satisfied, the delicate butterflies probably had become too weak to fly and had been eaten by the fire ants that patrolled the sites. Although I was relieved to learn that the butterflies had safely laid

Cajun cowboys, left, transport cattle from winter pastures on the mainland to a chenier, where they will be allowed to roam. Below: A cow grazes in the marsh bordering a chenier.

their eggs in preparation for the next year's generation, some questions still persisted. How could the larvae (the caterpillars) and, later, the pupae (the mummylike forms that eventually open to reveal the adult butterflies) survive the next eleven months in a habitat prone to floods? How could they survive the cattle's constant browsing and trampling?

Rather than hang about for who knew how long to watch the caterpillars hatch and develop, I collected a batch of twelve eggs and several host plants and brought them back to my home in Baton Rouge, 120 miles away. I planted the bitter cress in a three-foot-tall glass terrarium and set the eggs carefully on the plants' leaves. Within three to four days, all the eggs hatched. The small, yellow-green caterpillars quickly ate the eggshells and then crawled to the tips of the bitter cress to begin feeding on the delicate flower petals. As they matured, the caterpillars devoured more and more of the plant tips—buds, flowers, or new seed pods—never descending to feed on leaves. This behavior, I knew, was characteristic of falcate orangetip caterpillars. And the caterpillars' uncanny resemblance to the small seed pods that appear on the tips of the plants probably protects them from potential predators.

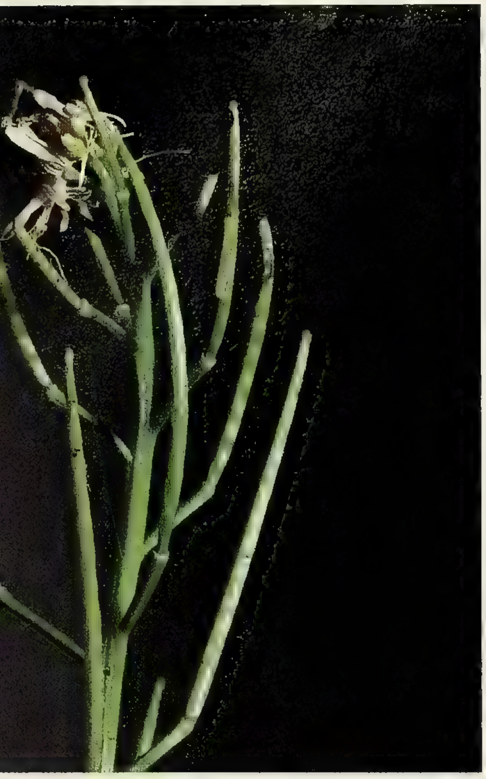
Bitter cress is a member of the mustard family, and the mustard oils the caterpillars consume while munching on the plants are believed to render them and the adult butterflies distasteful to predatory birds. Possibly the caterpillars avoid the leaves because the concentration of the oils in them is too high (cattle certainly avoid consuming bitter cress). In any case, by remaining on the top of their host plant, caterpillars that live on the cheniers significantly reduce their risk of drowning.

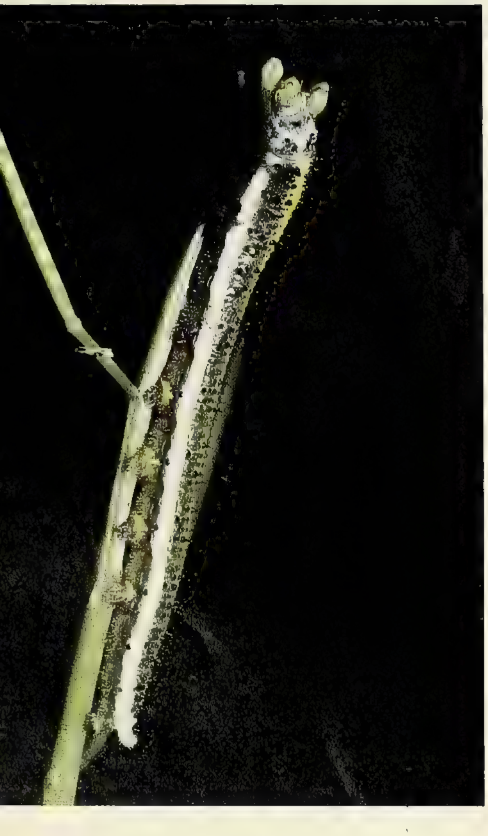
After three weeks, my twelve house-reared caterpillars changed from green to brown, an indication that they were nearing the end of their larval phase. It was time to see how the "wild" caterpillars were doing. I packed the terrarium, along with my other gear, into my truck and returned to the cheniers. There I observed that the formerly inundated habitats were now dry, except for a few natural depressions and many of the cattle paths. Most of the bitter cress plants had already gone to seed and were yellowish and withered. In damp depressions, however, I noticed some plants that were still quite healthy. On eight of them I found a few brown caterpillars.

I had a problem to solve, however. Where did the caterpillars pupate? They could not attach themselves to the bitter cress plants, which were soon to wither away. They needed a place where they could remain secure until the following March—nearly a year away. Using ice cream sticks, I marked the eight plants hosting caterpillars. When I returned to inspect the plants the following morning, I discovered that half the caterpillars were missing. The larvae apparently traveled at night. I would have to pull an all-nighter if I wanted to see where they went.

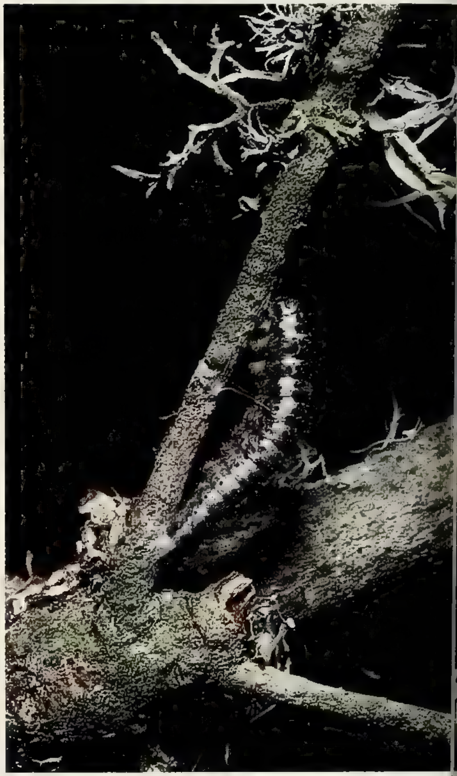
At dusk, I transferred four of the house-reared caterpillars onto the abandoned host plants. I then drenched myself with insect repellent, mindful of the local folk wisdom, "If you can't complete any outdoor activity by sunset, forget it!" (Mosquitoes in southern Louisiana often are so numerous that one has the impression that the air is vibrating.) With flashlight in hand, I located a more-or-less comfortable spot near the tagged plants, spread my

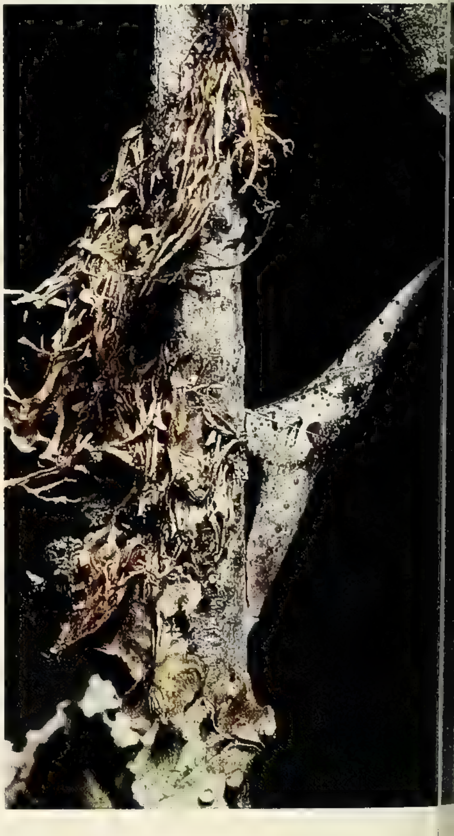
Blending in with the plant's seed pods, caterpillars of the falcate orangetip butterfly, below, grow to maturity on the tips of Pennsylvania bitter cress.





A caterpillar ready to pupate, below, attaches itself to a twig on a hackberry tree. Resembling a thorn, bottom, a pupa awaits the next spring.





poncho on the ground, sat down, and began to mark time.

In the wee hours of the morning, when I had just about decided that I had had enough of the misery, a break came. One of the caterpillars began to crawl down its host plant. Keeping my distance so as not to directly illuminate the caterpillar with my flashlight, I kept a watchful eye. The plump, brown caterpillar made its way to the ground and then continued onward. I followed. After traveling without pause about thirty feet onto slightly higher ground, the caterpillar encountered a small hackberry tree. It then crawled about ten feet up the trunk and rested. I remained with the caterpillar nearly a half-hour, but nothing further seemed to be happening. After marking the trunk with a strip of white cloth, I backtracked to check on the other three caterpillars. All three had disappeared from their host plants, so I began scanning the ground for them. After a while, the beam from my flashlight fell on something I did *not* want to see: a fat, two-foot-long water moccasin. Fortunately, the creature was slithering away. When I recovered from the shock, I spotted two of my caterpillars on the damp, bare ground, crawling to higher ground. When they encountered the bases of trees, they ascended to a height of six to ten feet. By four in the morning, they had begun to weave silken threads to attach themselves to the trees.

Satisfied that I now knew where the caterpillars would pupate, I made the rounds to check on all the other caterpillars. By this time, they, too, had departed from their host plants, presumably in search of trees. Finally, I returned to my truck to observe the eight caterpillars that remained in the terrarium. I found that they had crawled to the upper ends of some dead twigs I had provided for them, and had attached themselves to begin pupation. Exhausted but satisfied, I drove to my motel for a much-needed shower and a couple of hours of sleep.

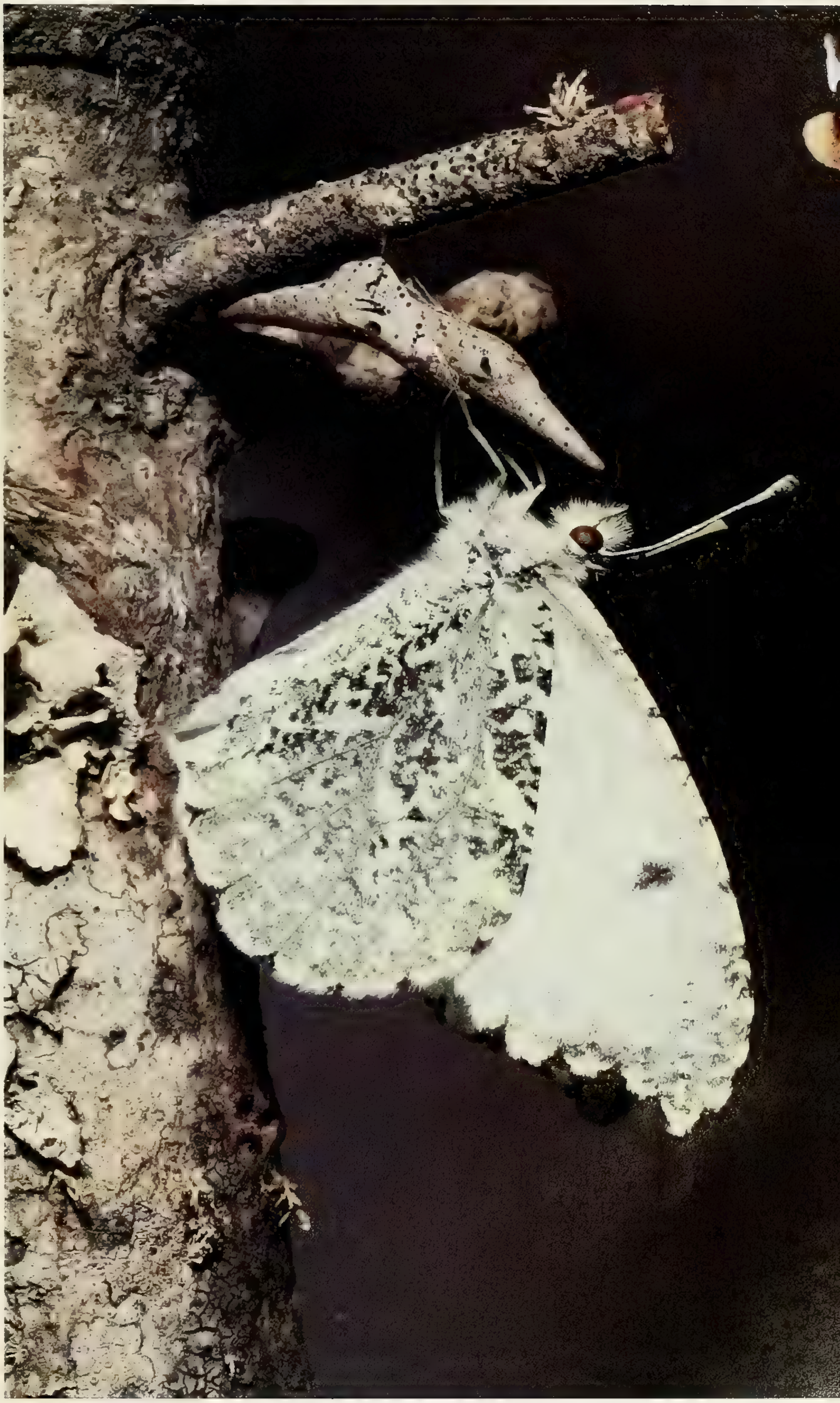
By midmorning I was up again and back at my research sites. Sure enough, the caterpillars were still on their trees. By late afternoon, each had shed its skin to reveal its pupa, which was anchored at its base and middle. Basic brown in color, with yellow, green, and tan mottling, the pupa has a pointed front end that makes it look very much like a thorn. This camouflage blends with thorns and bark protrusions on the trees, conferring protection on the developing butterfly. In addition, the pupa's high perch is secure from flood waters and marauding cattle.

My curiosity was mostly satisfied, but I was intrigued by one particular detail of my observations—the way the bitter cress plants seemed to flourish near the cattle tracks. I decided I should investigate conditions on a chenier free of cattle and people. I chose Little Pecan Island, which at 2,700 years is Louisiana's oldest extant chenier. As a result of extensive dredging to create navigational ditches and canals for petroleum exploration, this chenier is completely surrounded by open water, not marsh. Although it was homesteaded by a few families in the late 1800s, Little Pecan is now uninhabited, managed by the Nature Conservancy as a preserve for research and nature-oriented recreation.

In a two-day survey of the island I could find only two dozen bitter cress plants, all growing in a natural depression under the parasol-like branches of ancient live oak trees. None showed any signs of having hosted falcate orangetip caterpillars—I suspected there were too few plants to sustain a colony of falcate orangetips from one year to another. If ever the butterfly had lived there, it probably had died out a long time ago.

I came away from Little Pecan Island convinced that the cattle on the other cheniers played a part in making Cameron Parish hospitable to falcate orangetips. The cattle tracks create countless small catch basins that retain water long after the surrounding terrain has dried out. These damp habitats help the bitter cress plants grow larger and taller. This may matter little in a spring with normal rainfall. But during unusually dry years, which come along every now and then, the minipools are probably crucial to the plants and

A newly emerged falcate orangetip clings to its pupal case. "Falcate" refers to the hook-shaped tip of the forewing (lower right). The absence of orange wing markings shows that this is the female of the species.



therefore to the caterpillars. In addition, the churning of the ground by the cattle creates and maintains relatively clear areas free of competing, congesting vegetation. This promotes the dispersal of bitter cress, a pioneer species that does best in disturbed areas.

Cattle thus appear responsible, at least indirectly, for maintaining this small population of butterflies. How long this relationship has prevailed is hard to say. Most likely, before so many trees were cleared, the falcate orangetips were more widely distributed across the cheniers. The butterfly population may have been an eastern extension of the population in Texas. As the forest was cut down, the butterflies' foothold in the cheniers probably became more precarious, and the cattle became a significant factor in the survival of this isolated population. Alternatively, the butterflies and the cattle may have been introduced into the region at the same time. The least likely scenario, I think, is that the chenier butterfly population was once connected to the more northerly Louisiana population—the distance seems too great. Perhaps in the future, genetic tests will reveal how these various butterfly populations are related.

In 1992, after I returned to my home in Baton Rouge, I placed the terrarium containing the eight remaining pupae near a window. A year later, on March 19, 1993, two of the pupal cases split open to free two perfectly formed female butterflies. The following day, one male emerged. I drove to Cameron Parish to check my field site. All the plots were relatively dry because of the lack of heavy spring rains. On March 21 a single female appeared, and on the following day both a male and female were on the wing. By March 25, they had vanished. For the next four days I searched in vain for butterflies—this was probably the shortest flight period on record for a population of butterflies. But I did see a few of their orange eggs—on bitter cress growing in cattle tracks.

Another year passed. Because the weather was warm, I decided to place the terrarium with its five remaining pupae in an outdoor patio. On March 12, 1994, a shower during the night saturated the soil in the enclosure. To my surprise, between March 19 and 26, two females and one male emerged—a full two years after beginning their deep sleep. During this same period I observed relatively large numbers of adults throughout the four colonies in Cameron Parish. It was a bumper year for falcate orangetips. (Just before this article went to press, the remaining two butterflies in my terrarium—a male and a female—emerged from hibernation.)

A male falcate orangetip, below, rests on a bitter cress plant. A tiny orange egg nearby shows that a female has already paid a visit to the same plant. Right: A male and female court on a Louisiana iris.

What at first seemed to be a life strategy teetering precariously close to oblivion has turned out to be fine-tuned for survival. In a dry spring, when the bitter cress plants are unlikely to flourish, the butterfly pupae may remain in their mummylike state for another twelve months (perhaps for several years). But when the rains come, the butterflies will emerge, mate, and lay their eggs. The new generation of caterpillars will race through their brief life cycle and then, as pupae, lie low in their hostile environment. □

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by Hans Klingel

Fluctuating Fortunes of the Rive

As water levels rise and fall, so does the lot of the hippopotamus

Some 3,000 years ago, when the Greeks first encountered hippos in the Nile Delta, they were struck by the animal's similarity to the horse and so named the stocky creature Hippo Potamos (the river horse). We now know that hippos are not horses at all, but rather artiodactyls, cloven-hoofed ungulates like pigs, camels, deer, and antelopes. Unlike its relatives, however, the river hippo has adopted a truly amphibious lifestyle (hence its scientific name, *Hippopotamus amphibius*).

Water is at the center of the hippo's social life: mating, giving birth, playing, and fighting all take place exclusively or predominantly in water (not only rivers but also lakes, swamps, and wallows). If undisturbed, hippos may spend part of the day resting on the shore, but their primary trips onto land take place at night, when they may travel several miles overland to graze. Their unique lifestyle sometimes puts hippos at a disadvantage in comparison with other grazers. During the dry season or drought years, for instance, hippos have to wander farther and farther from the river to find food.

The hippo lifestyle can also be frustrating to the human observer. Studying hippos often means spending the daylight hours looking into water so murky that the only things visible are the tops and backs of a ceaselessly moving jumble of animals, and at the end of the day, one faces the challenge of following the hippos for miles in the dark to the mosaic of bushes and grasslands where they graze. Not surprisingly, much remains to be learned about these animals, and researchers are often forced to settle for scattered pieces of information, hoping they can eventually put together a complete story.

Efforts to reconstruct the hippo's past

Photographs by Christine and Michel Denis-Huot

lorse

Young male hippos, about two years old, play at the water's edge, readying themselves for more serious contests that will arise as they mature.

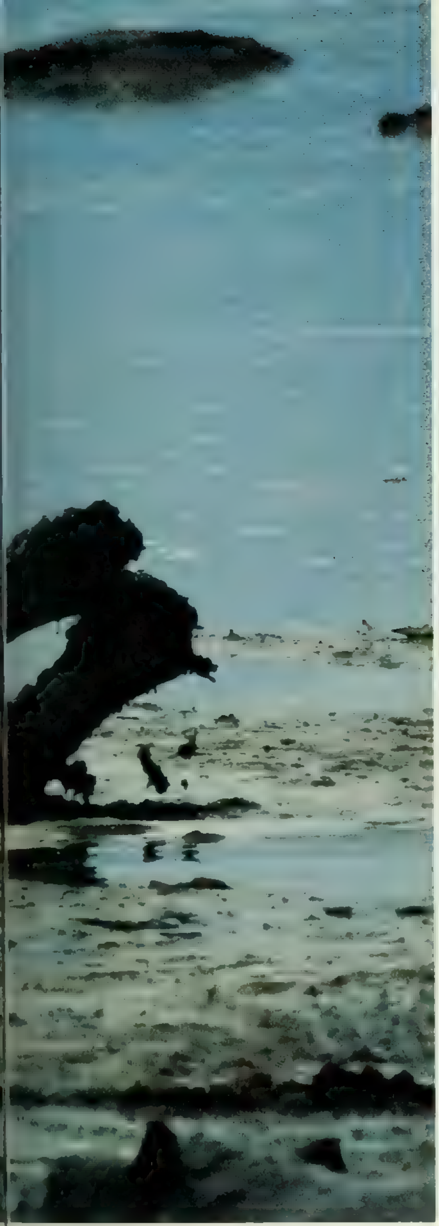
have also produced a somewhat fragmented picture. The fossil record suggests that the hippo's evolutionary history may have begun 25 million years ago, in the Oligocene, with the extinct anthracotheres. We know that many hippo species, belonging to several genera, lived over a period of millions of years, from the Tertiary to the Pleistocene. The earliest hippos appear to have been more terrestrial and less specialized than today's familiar river hippo. They were probably much like the earth's only other surviving hippo species, *Choeropsis liberiensis,* the pygmy hippo. A sedentary, solitary, terrestrial creature, the pygmy hippo lives in a small home range and browses on a wide variety of plants. Once more widespread, the species is today restricted to parts of West Africa.

The fossil record has also provided evidence of how the hippo family changed over time to include bigger species, with different skull proportions and teeth adapted to grazing, not browsing. During interglacial periods of the Pleistocene, hippos inhabited what is now central Europe and England. They also colonized islands, including Madagascar and Mafia Island off the coast of Tanzania. Also during the Ice Age, the Lake Turkana basin of northern Kenya supported four species of hippos, all of the genus *Hippopotamus.* Only one survived the dramatic climatic and ecological changes of the Pliestocene, which led to the extinction of so many mammals, and that one—the familiar *H. amphibius*—was once far more abundant than it is today.

In Roman times, the species ranged over much of what is now the Sahel and the Sahara, then a much more humid habitat, with permanent streams and lakes as well as grasslands. Only a few hundred years ago, hippos lived along the entire length of the Nile, and even today, they have a fairly impressive range through most of sub-Saharan Africa. An estimated 150,000 hippos remain on the continent.

Much of my own research has been concerned with the social organization of *H. amphibius* and how the species responds to changes in its watery environment. For no body of water is static: water levels may fluctuate dramatically, a river may change its course, a swamp may dry up. And as I have discovered during my years of fieldwork in Uganda's Queen Elizabeth National Park, the fortunes of the hippos fluctuate along with those of the waters they depend on.

I began my fieldwork at a difficult time. Idi Amin was in power and terrorizing the Ugandan people, and the economy of the country was in shambles. In 1979, Tanzanian soldiers invaded Uganda and chased



Left and overleaf: Hippos regularly wallow in mud, in part to protect the outermost layer of their skin from drying out. The yawning male at left reveals his greatly elongated lower canines. Displaying such impressive weaponry is often enough to discourage subordinates.

Amin out. In the process, they slaughtered untold numbers of wild animals, including buffaloes, elephants, antelopes, and many of the hippos I had been studying. But for four and a half years before that, the park itself was relatively quiet and safe, and because the hippos there regularly came out of the water during the day to rest on the shore, I felt I would be able to count, identify, and observe them well. I selected two study sites in the park: one on the Ishasha River; the other along the shore of Lake Edward at a place known as Mweya. (Every year since the war ended, I have returned to Africa to continue my studies on hippos. The hippo population has never fully recovered from those dark days, and poaching continues.)

The hippos became used to my daily visits and soon paid me no heed. Many times, as I sat on the shore of the Ishasha, I saw the immense head of a three-and-a-half-ton bull breaking the water's surface within ten feet of me. Typically, the bull would take a breath, look at me, and then disappear again for a few minutes. Similarly, I could observe a group of hippos on shore for hours and from less than 100 feet away. They appeared completely at ease and continued with their main activity—sleep. This setting was not only ideal for observing the hippos but it was also within reach of the laboratories of the Uganda Institute of Ecology.

I learned to recognize many individuals by the distinctive scars that most have as a result of fights and traveling through thorny thickets; many also had lost parts of an ear or tail to attacking hyenas. Unfortunately, most scars are visible only when the hippos are out of the water and, even then, only in the daytime. To increase our odds of recognizing individuals, my assistants and I immobilized seven hippos and marked them with ear tags and collars. The im-

Hippos Under the Gun?

by Keith Eltringham

The large river hippo, the more common of the two living species of hippopotamus, is found in much of Africa south of the Sahara, and visitors to wildlife parks with lakes or rivers are almost certain to see some. Nevertheless, although no reliable counts are available for the past, hippo numbers are believed to have declined over the past few decades, dramatically so in West Africa.

In the early 1990s, I conducted a survey, using questionnaires, direct counts, and correspondence; the result was an estimated 157,000 river hippos left on the continent. Southern Africa has the most, with about 40,000 in Zambia, 20,000 in Mozambique, 10,000 in Malawi, and 6,900 in Zimbabwe. Eastern Zaire supports about 30,000 hippos, and the rest of East Africa is home to some 40,000. Hippo numbers are lowest in western Africa, with only 7,000 living in scattered, fragmented groups. The pygmy hippo is now extremely rare, with probably no more than a couple of thousand remaining. This species is mainly confined to forests in Liberia, with small numbers in the three surrounding countries: Sierra Leone, Guinea, and Ivory Coast. (A small population of pygmy hippos also lived in Nigeria, but there have been no recent sightings, and I suspect it no longer exists.)

The main threat to the pygmy hippos is the loss of their forest habitat. Threats to the river hippo include the loss of grazing habitat to expanding human populations, especially in the west, and to hunting for meat. Poaching for the hippos' large canine teeth also appears to have increased lately, perhaps because the ban on elephant ivory has led ivory dealers and carvers to look for substitutes. In 1988, for example, just before the ban, 5,640 pounds of hippo teeth were exported from Africa; by 1991, the total had risen to 30,100 pounds, a more than fivefold increase.

One hopeful development is that the river hippo has recently been added to Appendix II of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES); this means that trade in the species must now be regulated. The pygmy hippo is on Appendix I (CITES's list of endangered species), which bans trade completely. These listings are a positive step; whether they can help the hippos withstand the pressures they face remains to be seen.

Keith Eltringham is in the zoology department at Cambridge University and is Chairman of the Hippo Specialist Group of the IUCN–World Conservation Union.

Hippos congregate in a wallow, below, surrounded by many well-worn trails. Right: A bull returns to water after making a short trip ashore to deposit dung on one of the many piles that line hippo trails. (The dark stain on his hindquarters reveals his mission.) At dusk, all but mothers with infant calves leave the water and travel several miles to their grazing areas.

mobilizations had to take place on the grazing areas, far from water; otherwise, disturbed hippos might retreat to their lake or river and, while drugged, drown. I marked another twenty animals, again at night and on land, by spraying paint on them with a hypodermic syringe. This was a quick, safe, and successful method, the drawback being that the paint lasted only for about three weeks. Because these marks showed up well in the moonlight and even better with a flashlight or a night-vision scope, the animals taught me much about hippo night life.

Hippos seem capable of forming almost every type of social grouping imaginable. Most congregate in groups, but a few, mostly bulls, are solitary. Some groups are made up exclusively of cows and calves; others contain a bull or two, and some consist primarily of bulls. Some groups are tightly packed; others may be dispersed over half a mile. The number of hippos in a group varies greatly, too, from as few as two to more than one hundred. Furthermore, these associations change frequently, often by the hour, as some members move away and others join. Analyzing the groups is hard work, and when the hippos are in the water, even the apparently simple task of getting an accurate count of a relatively small group (fewer than two dozen animals, for example) is often difficult and, at times, impossible.

Knowing the number of animals in a group is only the first step in a study of social organization. The next is much more complicated: determining the sex and age of the animals. Fortunately one category of hippos can always be identified with confidence: the adult bulls. Even when partly submerged, an adult bull is recognizable by his heavy build and massive neck, and when he yawns, his impressive, daggerlike lower canines, thicker than in cows or subadults, are clearly visible.

I soon learned that some 10 percent or so of the adult bulls dominated all the other hippos, male or female, but that their dominance was limited to particular, restricted places along the shore, which they monopolized as mating territories. (Luckily, all the dominant bulls in my study areas had notches in their ears, prominent scars on their backs and sides, missing tails, or other permanent marks by which they could be identified.) Any cow entering a bull's territory would be sniffed for signs of sexual receptivity; if she proved to be in estrus, the male would proceed to mate with her. Prior to copulation, male and female engage in a brief "courtship"

that can be quite rough and has often been mistaken for fighting. During the actual mating, there is no interference from other adult bulls, which are tolerated on the territory as long as they behave submissively.

Some territories were never or rarely visited by cows. The dominant bulls on them seemed to be at a double disadvantage: their success at mating was as poor as that of bachelors (that is, nonterritorial bulls), yet they still had to spend energy defending their territory, a seemingly useless patch of shoreline. As my study progressed, however, I learned that the quality of a territory, and therefore its attractiveness to cows, is not always constant: if ecological conditions change, a good territory may quickly become a bad one and vice versa.

Both territory size and length of a bull's tenure are variable. My Ishasha study area was a half-mile stretch of river. The Ishasha is modest in size, from eighty to

three hundred feet wide, and from three to fifteen feet deep (depending on the season). A riverine forest lines its sandy banks. Along the stretch I studied, the territories ranged from fifty to one hundred yards along the shore; periods of tenure varied from a few months to more than two years. My Mweya study site was a stretch just under a mile along the lake shore. There, grass grew right up to the edge of the lake, and the water was very shallow: one hundred feet out from shore the water was only three to five feet deep. At Mweya, territories ranged from 150 to 500 yards, and for the four and a half years of my investigations, neither territory boundaries nor their owners changed. This stability was largely due to the constancy of conditions there; the lake level remained roughly the same over the years.

After my initial study, my Ishasha site became unsuitable for hippos: the river changed course and was very shallow in places, with trees growing where water had been. Mweya, in contrast, remained hospitable hippo habitat. On all my visits there, I kept a lookout for familiar hippos, particularly for my territorial bulls. Eight years after first recording them, I found two were still on the same territories; even after twelve years, one was still in possession of his territory. Although I have no proof that these individuals were territorial for the whole period, I have little doubt that they were, and I believe that their territorial tenures are among the longest recorded for any species. Because only about one bull in ten held a territory in my study areas, the great mating success of these fortunate few translated into little or no success for the rest.

The situation at my Ishasha River site was quite different. Unlike Lake Edward, the river was changeable. Floods regularly alternated with periods of low water. The effect was obvious: at low water, some of the territories fell dry, and their owners either started a new territory elsewhere or joined bachelor groups. When water levels rose, new places became suitable and were occupied, sometimes by bulls new to me, sometimes by bulls that had held territories previously, and sometimes by territorial bulls extending their domain. When the river was in flood and the water running fast, all the hippos moved out of my study area. Some settled in what was for me an inaccessible dead meander farther downstream, but most moved to a newly formed swamp a few hundred yards away from the river. There, some of the bulls immediately began to carve out new territories for themselves.

My two study areas also differed in the density of the hippo populations they supported. At my Mweya site, there were, on average, about seventy hippos, which translated into about five animals per 100 yards of shoreline. At Ishasha, where up to

Hippo bulls fight for control over mating territories. Some fights are ritualized, with no damage to either animal; others may lead to deep gashes and crippling bites. The stakes are high: territorial males garner the vast majority of all matings.

250 hippos came together, there were thirty individuals per 100 yards. The social scene in Ishasha was also influenced by the presence of a group of 100 mature bulls living just a mile away; consequently, competition for the possession of a territory along the river was high. In contrast, the bull groups nearest to my Mweya site were several miles off.

As valuable as a good territory is, and as vigorously as a bull may compete for one, it is no guarantee that he will sire more offspring than any other territorial bull. A bull will certainly try to keep an estrous cow on his territory and mate with her, but he has no way of monopolizing her. If she decides to move on, she will do so, and she is free to mate with any number of bulls as she passes through their territories. One result of this movement is that no social group is isolated genetically.

At dusk, after a day of social activities, the animals leave the water and head off to

Hippo Talk

by William Barklow

Much of hippo social life takes place when the animals are completely underwater, and—as work that my students and I have been conducting in Tanzania's Ruaha National Park reveals—a submerged hippo can produce an impressive array of underwater sounds.

Some sounds—grunts, growls, and screams—are underwater versions of noises hippos make when their heads are out of the water. Some are quite loud: I recorded one underwater scream at 115 decibels. Often the only signs of such intense vocalizations are the fountains of water that erupt as air exhaled by the hippos hits the surface. Sometimes—such as when the vocalizing hippo is not far below the surface—this air forms a bubble that explodes at the surface with an infrasonic thud. After producing such a bubble blast, a hippo may rise to the surface and, keeping its head low and its ears forward, direct an aggressive stare at a nearby subordinate.

Other hippo sounds are produced only underwater and without any noticeable expiration of air. One of these—the most common sound made by hippos—is a simple croak. Given most often when calves and subadults are playing near their mothers, this call is probably used to maintain contact in murky water.

Hippos also produce a variety of high-pitched underwater whines. Some are similar to notes in humpback whale songs, while others (for example, a sustained note of unvarying pitch and lasting a full five seconds) are unlike anything I have heard before.

For me, the most intriguing of the hippos' underwater sounds are the various types of clicks they make, usually in a series. These "click trains" bring to mind similar sounds of cetaceans (whales and dolphins) and pinnipeds (seals, sea lions, and walruses). Dolphins and other toothed whales use their clicks in echolocation as they navigate and search for food. (The function of pinniped clicking is unresolved.) Most hippos live in environments where echolocation would certainly be useful: the waters of African lakes and rivers are usually clouded with silt and strewn with boulders and other obstructions. So far, however, there is no evidence that hippos echolocate. I, for one, have never heard hippos click as they move, sometimes for hundreds of feet at a time, beneath the water surface.

All hippo clicks that I have been able to correlate with behavior of any kind have been given during social interactions. At the Toledo Zoo's large hippo pool (one of the few places with clear enough water to watch submerged hippos), I once watched a male and female perform a mating dance as graceful and balletic as that of the animated hippos in Walt Disney's *Fantasia*. Part of this ritual involved a gentle clashing of their huge lower canines and incisors. A sound recording showed the clashes to be identical to a click category recorded in the field. Perhaps some of the clicks, then, are associated with courtship. Other clicks, like some whines, may play a role in the frequent jostling for position that is part of the hippo social scene.

The effort to decipher the meaning of all these grunts, screams, croaks, clicks, and whines is just beginning. And underwater sounds are only part of the hippos' system of communication; other sounds transmit above and below water simultaneously. To fully understand these "amphibious" sounds, we will need to learn more about how hippos hear. I suspect that they can hear in air and water at the same time, and I hope one day to determine whether a big bull hippo, after growling aggressively below the surface, can then listen for the amphibious screams of his intimidated neighbors.

William Barklow, a professor of biology at Framingham State College in Framingham, Massachusetts, has also worked for years on the calls of loons in Maine.

aze. Well-worn exit paths are numerous
ong the shore, but the hippos do not nec-
sarily use the nearest one. In one place at
Iweya, they regularly traveled almost a
ile in the water parallel to the shore to an
it that was closer to the grazing area.
ecause many hippos may use the same
it paths (especially if the riverbanks are
eep), some of these bankside exits may
worn five or six feet deep, becoming al-
ost tunnellike. As the hippos file out,
early nose to tail, they give the appear-
nce of togetherness, but after moving
me distance from the shore, they dis-
rse; nighttime grazing is not a social ac-
ity. The only social group one sees at
ght is a mother with her young: offspring
rn that year and subadults from previous
ars. Young hippos are vulnerable to a
st of predators—hyenas, lions, leop-
ds, and crocodiles—and benefit from the
otection of their two-ton-plus mother.

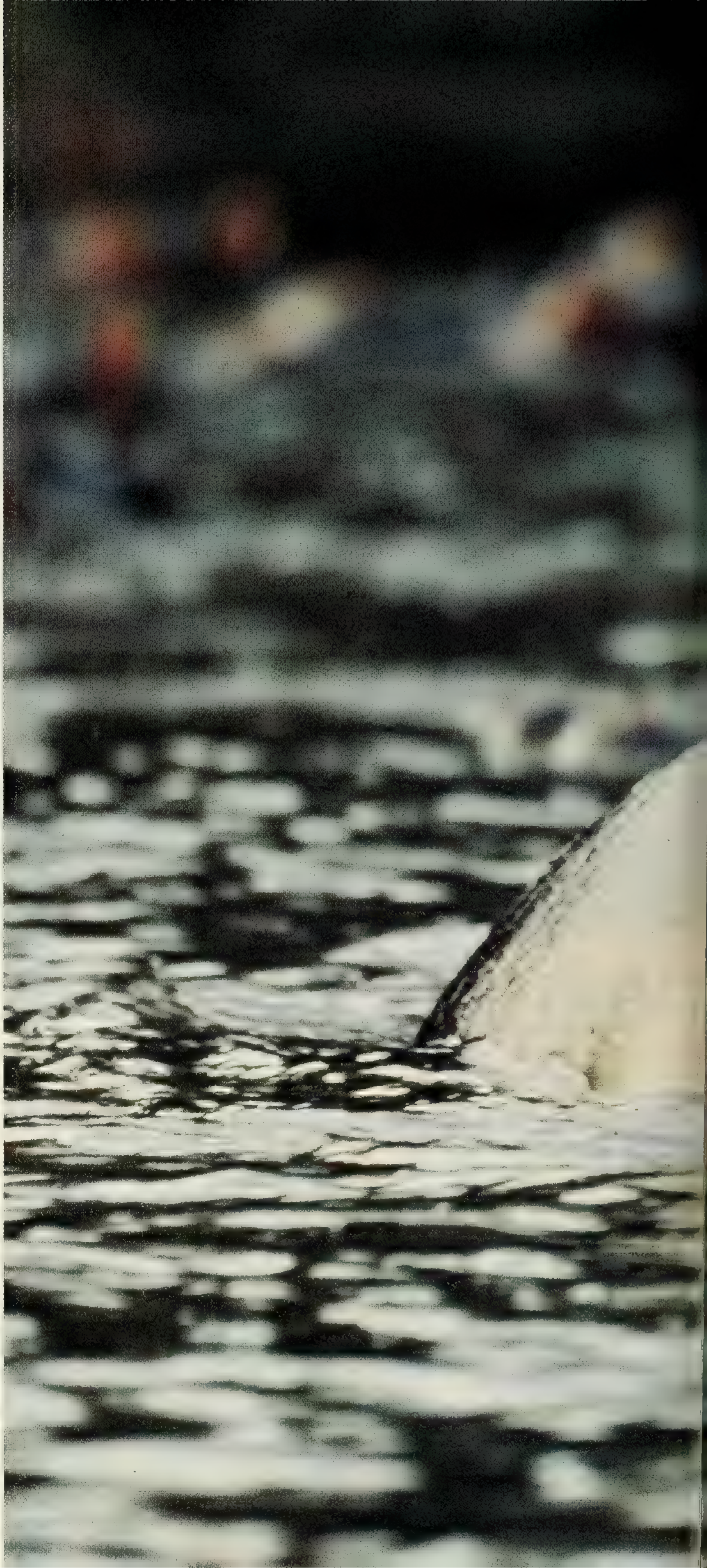
Hippos usually feed throughout the night, returning to the water by dawn. Many go back to the same place in the river or lake they left the previous evening, which gives an impression of group stability. But there are always some who settle elsewhere: sometimes nearby, sometimes miles away. Only the territorial bulls can be absolutely relied upon to return.

On many occasions, my students and I watched the hippos leave the water in the evening and then waited for them to return in the morning. Their eyes reflect light, so I could scan the water with a flashlight to find out if and when they had all left. Within a couple of hours after sunset, all hippos typically moved out, with the exception of mothers with very young calves, which stay in the water and don't eat at all for several days. Sometimes I recorded hippos coming back to the water about midnight, and to my surprise, they returned to rest, not to stay. After a few hours, they climbed out on land again, disappeared into the bushes, and most certainly went back for second helpings.

I found it impossible to follow the hippos any distance from the water; the terrain was a mixture of thick forest, thickets of bushes, and gulleys. Many nights, after driving around in the dark in my van, I met up with my marked animals at the grazing areas, and then I could observe them for hours. Inevitably, I lost them again whenever they entered large thickets, some of which were more than an acre in size, or when they decided to walk down steep slopes where I couldn't follow. One night I stayed with one of my hippo cows and her two subadult sons until they disappeared into the bush. When I drove around to catch up with them on the other side, I met other hippos coming out, but not my friends. After some time, I decided to search for them.

From the top of the van and with the help of a powerful flashlight, I saw some-

The hippo's small ears, eyes, and nostrils sit relatively high on its head, an adaptation to its amphibious lifestyle. After taking a breath and surveying its surroundings, this hippo can simply close its nostrils and eyes, fold its ears, and submerge, staying under water for up to five minutes.



thing absolutely unexpected: they were sound asleep on the grassless, sandy ground inside the thicket. This had been observed only once before, by naturalist Jonathon Kingdon. Subsequently, in Uganda and in other parts of Africa as well, I discovered many such sleeping retreats, which can be identified by an impression in the sand the size—not surprisingly—of a hippo and further characterized by a pile of dung at one end.

Whenever I come across a hippo asleep miles from the safety of its watery home, I am impressed. The shape of these animals, together with their short legs and generally thick skin (which acts like an energy-saving diving suit in the water, but causes them to overheat quickly in the heat of the day), makes them seem unlikely candidates for long-distance movements. Yet hippos must regularly undertake considerable journeys. Every night, they are obliged to travel for food, and in times of severe drought, they have been observed migrating in search of water. At first, they just continue in their usual manner, walking farther and farther to their deteriorating grazing areas and returning to an increasingly dried-up pool. By the time they decide to abandon the pool for good, many—especially the young and the very old—are too weak to follow and fall prey to lions and hyenas. The healthy and the strong, however, are capable of traveling long distances. In South Africa, one hippo became famous when it traveled 1,000 miles overland. This particular animal never settled for long, although it did find suitable habitats on the way. Unfortunately, this natural experiment came to an abrupt end when the hippo was shot.

As for the hippos I study, I hope they will not be forced to leave the shores I have come to know so well. Drought is only one of the many problems hippos will have to face as the millennium draws to a close. Only time will tell if the hippos—sole survivors of their kind—will outlive the habitat loss, fragmentation, poaching, and other pressures confronting so many of Africa's large mammals. ☐

In 1950 the West Indies and England played a colonial game

Cricket in the Blood

by Samuel M. Wilson

June 24, 1950, was a glorious day at Lord's Cricket Ground, which with Ascot and Wimbledon make up the heart of London society's sporting scene. The Royal Standard flew from the mast above the pavillion, signaling that King George VI was in attendance. The West Indies team was meeting England for the second in a series of four cricket matches. These were Test matches, that is, first-class (top-level professional) games between national teams. Actually, the West Indies side was multinational.

The Test Series of 1950 came at a critical time in Great Britain's associations with its colonies. In the years following World War II, India, Pakistan, Ceylon (Sri Lanka), Jordan, and Israel had become independent. Leaning more and more toward independence were the many British colonies in and around the Caribbean, including British Guiana (Guyana) on the South American mainland, British Honduras (Belize) in Central America, and more than a dozen major islands. A half century earlier, before the two world wars, the British Empire had embraced a quarter of the earth's population and twelve million square miles, an area about the size of the United States, China, and the former Soviet Union combined. By 1950, the trends against colonialism and toward self-government, coupled with the emergence of a new global economy and balance of power, had reduced the empire to a third of its former size.

The West Indies had played Test Series in England before, in the summers of '28, '33 and '39, but they had never won a single match. And two weeks before, at the Old Trafford cricket oval in Manchester, their initial meeting in this series had gone

Schoolchildren play cricket in Barbados, a country renowned for producing professional cricketers. Opposite page: Curtly Ambrose of Antigua, a fast bowler, helped the West Indies defeat England in the 1990 Test Series held at Saint John's.

Both photographs by Patrick Eagar

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The 1950 West Indies Touring Side that challenged England on British soil included (back row, left to right) C. B. Williams, R. E. Marshall, A. L. Valentine, L. R. Pierre, C. L. Walcott, H. H. Johnson, A. F. Rae, K. Testrail, Mr. Ferguson (baggage manager), and (front row, left to right) S. Ramadhin, P. Jones, F. M. Worrell, Mr. Barnes (assistant manager), J. D. Goddard (captain), G. E. Gomez, J. B. Stollmeyer, R. J. Christiani, E. Weekes.

JSS/Keystone; Hulton Deutsch Collection

badly. During their first innings (the first of their two times at bat) England scored 312 runs, and the West Indies side was only able to answer with 215. By the end of the match—which took only three days, plus an hour on the morning of the fourth, short by International Test Cricket standards—England had scored a total of 600 runs, beating the West Indies by 202. (For a brief explanation of how runs are scored in cricket, see "It's How You Play the Game," page 63.)

To those who do not know cricket, the scores may seem astronomically high and the pace glacially slow and mind numbing. Each match takes up to five days, with play lasting about six hours each day, and the sides in Test Series play four or five such matches. The deliberate pace is part of cricket's charm for its devotees. International series between favorite rivals come infrequently, so they are a delicacy that can be savored over a whole summer. The cricket fan can make occasional visits to the television to see how things are proceeding or leave the radio on softly all day, letting the BBC announcers, in their endless rambling dialogue, communicate with some subliminal part of the brain. The long matches can be exquisite torture as well, for sometimes one team is so badly behind by the end of the first day that it is very unlikely to recover, but the match must be played out over the next few days to be sure. Jobs are lost in the summers of Test Series; marriages wrecked.

Despite the first defeat, there had been a glimmer of hope for the West Indies' fans in the first Test match. Two young bowlers, just twenty years old and unknown in the cricketing world, had made a strong showing. Jamaica's Alfred Valentine had virtually no experience in first-class cricket, but he dispensed with England's first eight batsmen, allowing only 104 runs. It looked as though he might take all ten wickets, that is, put out all ten batters in the first innings, but his partner Sonny Ramadhin of Trinidad took the final two. Ramadhin was the first West Indian of South Asian ancestry selected for a West Indian side.

Ramadhin and Valentine were "spin" bowlers. All bowlers hurl the ball with a straight arm down the long cricket pitch, trying to hit the wicket on one bounce. The heavily padded batsman stands to one side in front of the wicket and attempts to protect it by hitting the oncoming ball with the bat. Fast bowlers (the kind the West Indies have since become famous for) come tearing up to the pitch with a long run-up, leap high in the air, and fire the ball at speeds in excess of ninety miles per hour. Spin bowlers take a shorter, more leisurely run-up and throw the ball more slowly,

On the second day of the 1950 Test match at Lord's, below, the bails flew off the wicket as a ball bowled by the West Indies' Sonny Ramadhin got by England's batsman Cyril Washbrook. The catcher behind the wicket was Clyde Walcott; the other fielder was Prior Jones. Bottom: Walcott, at bat, protects his wicket on day three of the match.

Photographs by C. E. Seymour; S and G Press Agency

about fifty miles per hour. But they put tremendous spin on the ball, so it bounces off at odd angles. There are leg-spinners and off-spinners, orthodox and unorthodox spinners, and they bowl flippers, wrong'uns, googlies, and other balls analogous to baseball's change-ups, sliders, and so forth. Ramadhin and Valentine's combination of spin-bowling styles was to prove exceedingly difficult to bat against.

Saturday, June 24, was the opening day of the second Test. "The Three W's," Clyde Walcott, Everton Weekes, and Frank Worrell—who were the same age and had grown up near one another on Barbados—were the heart of what would emerge as a formidable batting side. Batting first, the West Indies ran up 326 runs in their first innings, a very good start. They batted all that day and into Monday morning (Sunday being a day of rest).

Ramadhin and Valentine then devastated the English in their first innings, allowing only 151 runs. Valentine was an orthodox left-arm spinner who bowled with technical precision and tremendous accuracy. Ramadhin just baffled the batsmen with a peculiar delivery that made it nearly impossible to see how he released the ball or how it was spinning. Ramadhin took five wickets and Valentine four. Prior Jones took the tenth wicket.

Sonny Ramadhin's bowling was portrayed in the British press as mysterious, indecipherable, exotic. Indeed, the whole West Indian side seemed exotic to British spectators, many of whom had never seen people of color. While a recent census puts England's West Indian population at about half a million, in 1950 only 10,000 people from the West Indies lived in Britain. South Asians were just as rare. In his memoirs, *Island Cricketers,* Clyde Walcott describes an encounter he had that summer with an older woman:

> [She] walked past me, gave me an odd sort of look, stopped and came back. She came slowly and warily up to me then, seeming to pluck up courage, rubbed her fingers along my hand and stared at them. But the colour doesn't come off!

The tour presented difficulties for the West Indian players, who came from British Guiana, Barbados, Trinidad, and Jamaica. For example, they came to hate the bland fare of meat, potatoes, and cabbage, but couldn't get their hotels to substitute West Indian dishes such as rice and spiced curries. Still, the greatest source of annoyance for the West Indians was that they were seen, in the press and in the cricket oval, as inferior cricketers. The West Indies had previously beaten English teams, although not in England, and were fielding a strong team in the summer of 1950. They resented being taken lightly.

Of the colonial or former colonial nations, only Australia was regarded in England as a force to be reckoned with. Australia's victory in the Test Series of 1882, the first time England had been defeated on their home ground by a colonial team, had been a climactic event. The following day the *Sporting Times* printed an obituary:

> In Affectionate Remembrance
> Of
> ENGLISH CRICKET
> WHICH DIED AT THE OVAL
> On
> 29th August 1882
> Deeply lamented by a large circle of sorrowing friends and acquaintances
> R.I.P.
> N.B.—The body will be cremated and the ashes taken to Australia

Ever after, the Test matches between England and Australia had been seen as

In 1990, Australia competed with England at the Melbourne Cricket Ground. The two sides cultivate an intense rivalry that goes back to 1882, when Australia first defeated England on British soil. Australia won the 1990 Test Series.

Patrick Eagar

"playing for the Ashes." (The rivalry continues to the present day, so much so that Margaret Thatcher commented, "The world's a better place when we beat the Australians at cricket.") But the West Indies were not yet accorded that respect. With evident irritation, Walcott remembers an English cricket official describing the series as "a good opportunity to try out some of the English youngsters for the tour of Australia in the winter," and saying that the West Indies could at least be counted on to play "entertaining" cricket.

When the West Indies came to bat for their second time, late Monday afternoon, England had to prove that the first innings had been a fluke. But the English bowlers could not mount a rally to equal Ramadhin and Valentine's performance. The West Indian batsmen were on a tear, setting records that still hold—Walcott and Gomez put on 211 runs, a record partnership. Walcott alone accounted for 168, and would have added to it, for he was still not out on Wednesday morning when the West Indies "declared," with only six wickets fallen. By declaring, they made the strategic decision to bring the English side to bat, allowing sufficient time to complete the innings (otherwise the game might end in a draw).

On Wednesday and Thursday, try as they might, England could not catch up to the 751 runs scored by the West Indies, and went down to defeat by 326 runs. When the final English batsman fell to Frank (now Sir Frank) Worrell's bowling, West Indians in England and throughout the Caribbean celebrated. Writing in *The Cricketer*, the famous cricket commentator E. W. Swanton described the jubilant scene: "Some [of the West Indians], armed with impromptu instruments, saluted the great occasion with strange noises and a handful with their leader swayed round the field to give a faint reminder to those who know the West Indian islands of the bands at carnival time."

In his memoirs, Clyde Walcott says, "This was *our* finest hour, with 'those little pals of mine, Ramadhin and Valentine' the special heroes." He was quoting from a popular calypso by Egbert Moore that spread throughout England and the Caribbean. The first verse went:

Cricket, lovely cricket,
At Lord's where I saw it;
Cricket, lovely cricket,
Yardley tried his best
But Goddard won the test.
They gave the crowd plenty fun;
Second Test and West Indies won.
Chorus:
With those two little pals of mine
Ramadhin and Valentine.

That Friday, the lead article in the *London Times* gave the West Indies side their due: "Yesterday was their finest hour. They have handsomely laid an All England XI low at Lord's. . . . To win by 326 at the headquarters of cricket, in spite of the

It's How You Play the Game

Cricket is played by two sides of eleven players each. The sides take turns batting and fielding, and each side comes in to bat twice. The cricket field is an oval with a long axis of from 100 to 150 yards. In the center of the field is the pitch, a carefully prepared rectangle of closely mown and rolled grass. Two wickets are located 22 yards apart, one at each end of the pitch. (A wicket is three upright sticks, the stumps, with two pieces of wood balanced on top, the bails.)

Two batsmen from the batting side are on the pitch at the same time, one at each wicket. The bowler from the fielding side releases the ball from behind one wicket toward the other (the direction is periodically altered). The ten other fielders are deployed around the oval. The fielding positions include the wicket keeper, who catches the ball and throws it back to the bowler, a number of "slips" beside him to catch barely deflected balls, and an array of others at positions called gully, point, cover, mid-off, square leg, and so on. (If they stand right up close to the batsman their position is called, because of the risk, silly mid-off, silly point, and so on.)

The batsman toward whom the ball is thrown must protect his wicket from the bowled ball and also attempt to score runs. When the batsman hits a ball, the two batsmen may run down the pitch, changing places. That scores one run. If the ball is hit far enough for them to do so safely, they change places again, scoring as many runs as they can. If the batsman hits the ball to the boundary fence he scores four without having to run, and if he clears the boundary with a fly ball, he scores six.

If the bowler can get the ball past the batsman and knock off a bail, the batsman is out. The batsman is also out if he hits a ball that is caught on the fly or if he tries to run but does not make it to the other end of the pitch before the fielders get the ball back in and knock the bails off the wicket. If the batter deflects the ball with his body or pads, instead of his bat, and keeps it from hitting the wicket, he's out "leg before wicket." When ten batsmen have been retired, the fielding team comes in to bat.

A match is over when both sides have completed their innings or when the time limit is reached. If the side that is behind has not finished its last innings by the end of the final day's play, the match is a draw. To prevent a draw, the winning side can attempt to speed things along by "declaring"—ending their innings before all the batsmen have batted—or by skipping their second innings altogether.—*S.M.W.*

A female batter, below, is no oddity: women's teams play cricket at all levels, from local matches to international series, including the annual Women's World Cup. Opposite page: West Indian Brian Lara played for the English county team of Warwickshire against Surrey in a 1994 match at Edgbaston. (Ever since the 1950 Test Series, West Indian players have been recruited by first-class cricket teams in England and worldwide.) In 1994, playing for the West Indies against England, Lara set the record for the highest individual score in a Test match—375.

Tony Henshaw; Professional Sport International

brave English recovery led by Washbrook on Wednesday, puts these West Indians for good among the great ones." The article concluded that "West Indian cricket has come of age."

The obvious comparison was with children reaching adulthood. An older British executive I once met on a plane described the 1950 Test in even more explicit terms: "It's like when your son beats you at squash for the first time, isn't it? You regret it and try harder next time, but there it is; it was bound to happen."

For England, the loss was a reminder that the empire was slipping away. The two events may even have been linked to similar historical forces. The patronizing comparison with a child's coming of age was misplaced, however. To cast colonized people as juvenile made no more sense than to portray post-World War II Britain as senile. The world had changed dramatically, and the British Empire of old simply could not exist in the new order.

The West Indian victory was sweeter for having come at Lord's, which Australian Prime Minister Sir Robert Menzies called the great "cathedral of cricket." Walcott noted that "had it come at Trent Bridge or the Oval, at Old Trafford or Headingly, it would still have been a great moment. But it was at the very heart of the game we love . . . and *that* gave the occasion its greatest thrill."

After Lord's, the four-game series stood even. In the next Test, at Trent Bridge, Nottingham, the West Indies proved that the Test at Lord's hadn't been a miracle. They beat England decisively, setting several personal and team records. The final Test match was held at the Oval, Kennington, and was one of those matches in which the outcome was determined in the West Indies' first innings. They scored 503 runs, and then Ramadhin and Valentine were able to hold the English batsmen to 274 runs. With their victory, the West Indies took their place among the best of the cricketing nations. Since 1950 they have been one of the dominant forces in world cricket.

Although the colonial era left deep scars and resentments in Britain's former colonies, in most cases these countries became independent without great bloodshed. Most became members of the Commonwealth, whose charter gave them equal status with Britain. Perhaps emblematic of this relatively peaceful transition, the former colonies' passion for cricket did not diminish with independence. This was especially true for members of the International Cricket Council—the West Indies, New Zealand, Australia, Sri Lanka, India, Pakistan, South Africa, and Zimbabwe (the council also included many affiliate and associate members).

In *The Tao of Cricket: On Games of Destiny and the Destiny o Games,* which is more a discussion of colonialism and postcolonialism than of cricket, the Indian intellectual Ashi Nandy comments ironically on his countrymen's complete assimilation of the game:

> Cricket is an Indian game accidentally discovered by the English. Like chilli, whic was discovered in South America and cam to India only in medieval times to becom an inescapable part of Indian cuisine cricket, too, is now foreign to India only according to the historians and Indologists. T most Indians the game now looks more Indian than English.

The West Indians feel the same way. A Clyde Walcott writes, "Indeed, cricke comes naturally to the West Indian and think it's true to say that it is always in hi blood." □

UNIVERSE

The Shapley–Curtis Debate

by Neil de Grasse Tyson

The history of ideas about our place in the universe has been a long series of letdowns for those who like to believe we are special. Unfortunately, first impressions have consistently fooled us—the daily motions of the sun, moon, and stars all conspire to make us think we are the center of everything. But we have learned a thing or two over the centuries. There is no center of Earth's surface, so no culture can claim (geometrically) to be in the middle of things; Earth is not the center of the solar system, it is just one of nine planets in orbit around the sun; the sun is 26,000 light-years from the middle of the Milky Way and revolves anonymously around the galactic center along with a hundred billion other stars; and the Milky Way is just one of a hundred billion galaxies in a universe that actually has no center at all.

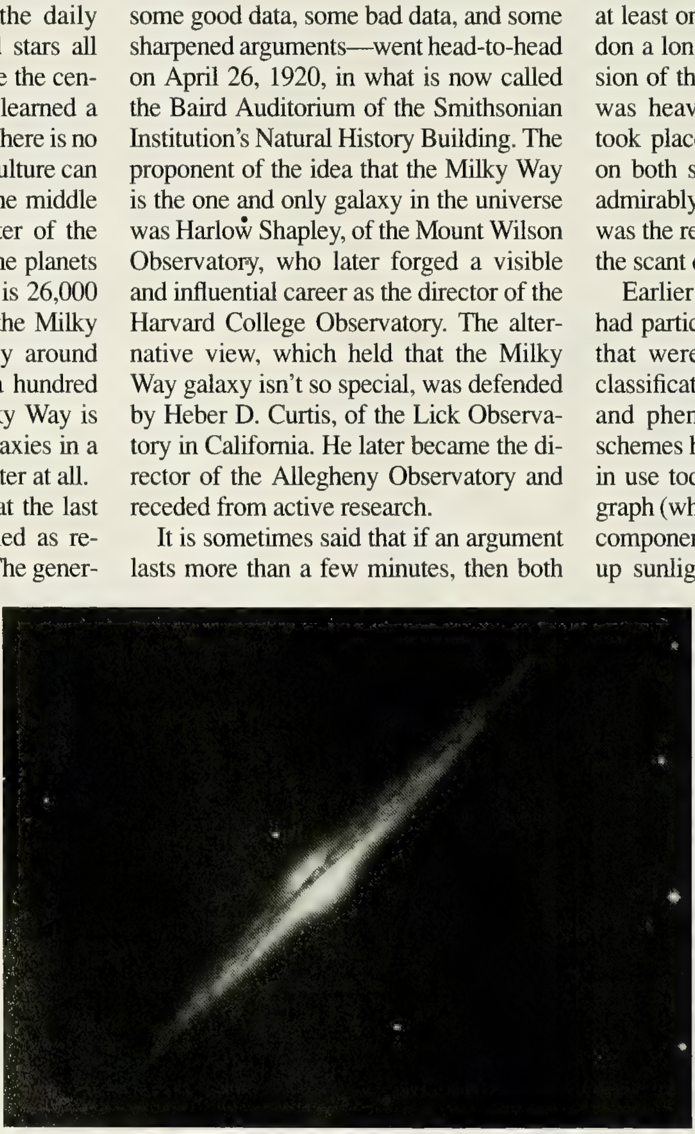
It is humbling to consider that the last two letdowns were each revealed as recently as the twentieth century. The generally recognized turning point occurred seventy-five years ago this spring when a now-famous debate on the extent of the known universe was held at a meeting of the National Academy of Sciences in Washington, D.C. The topics discussed included questions of fundamental importance: Was everything in the sky—stars and star clusters and gas clouds and fuzzy spiral things—all part of the Milky Way galaxy? Or were those fuzzy spiral things galaxies unto themselves, just like the Milky Way, dotting the unimaginable vastness of space like "island universes"?

Scientific discovery, unlike political conflict or public policy, does not normally emerge from democratic voting, party-line politics, or public debate. But in this case, two leading scientists of the day—each armed with some good data, some bad data, and some sharpened arguments—went head-to-head on April 26, 1920, in what is now called the Baird Auditorium of the Smithsonian Institution's Natural History Building. The proponent of the idea that the Milky Way is the one and only galaxy in the universe was Harlow Shapley, of the Mount Wilson Observatory, who later forged a visible and influential career as the director of the Harvard College Observatory. The alternative view, which held that the Milky Way galaxy isn't so special, was defended by Heber D. Curtis, of the Lick Observatory in California. He later became the director of the Allegheny Observatory and receded from active research.

It is sometimes said that if an argument lasts more than a few minutes, then both sides are wrong. A splendid aphorism, but there are at least two other causes of a protracted disagreement: One is insufficient quality or quantity of data; another is that at least one party is too stubborn to abandon a long-held view. The published version of the Shapley–Curtis debate, which was heavily edited from what actually took place, reveals a bit of stubbornness on both sides, but both scientists argued admirably, and what mattered in the end was the relative confidence each placed in the scant data available.

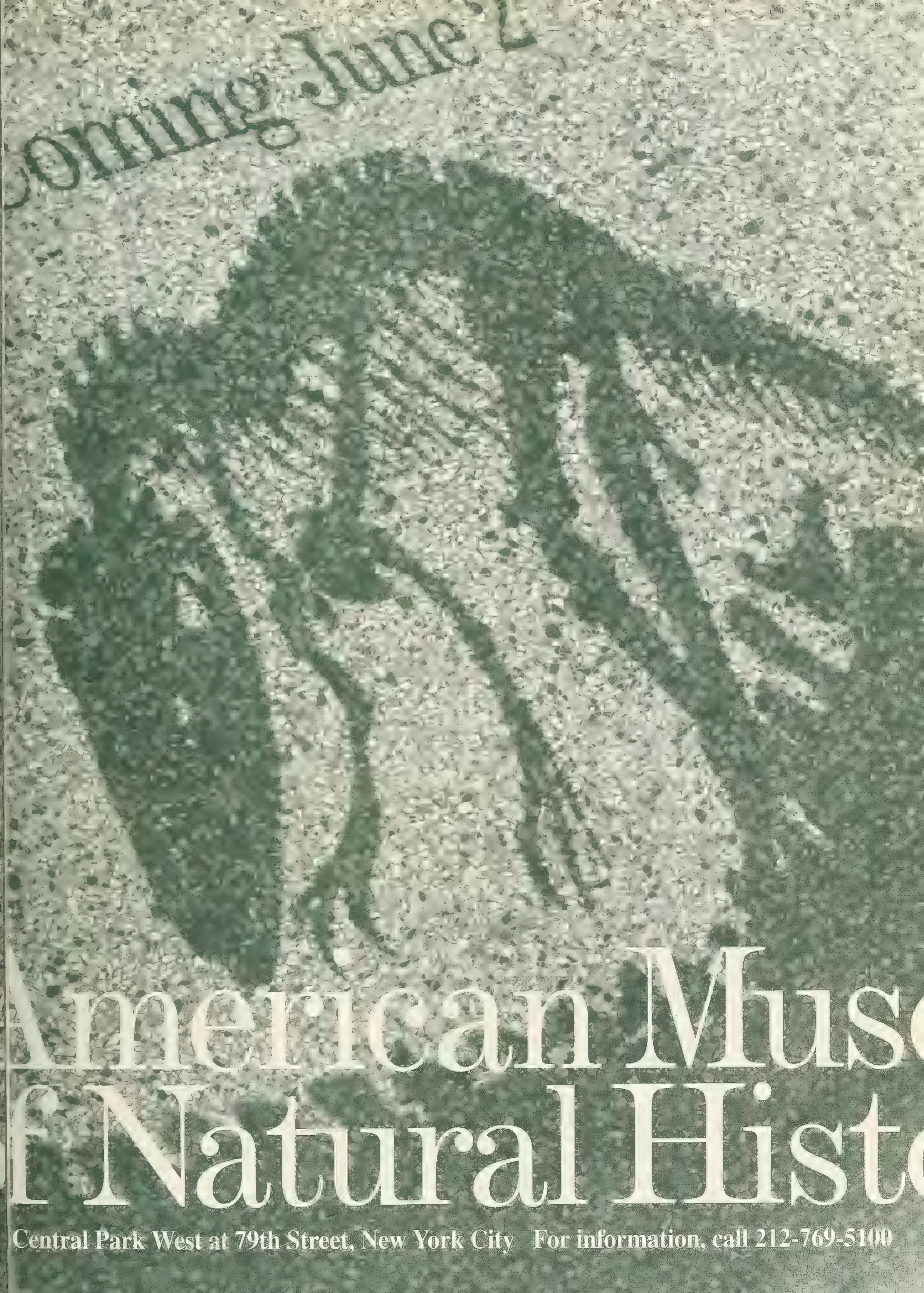
Earlier in the century, both scientists had participated in a wave of discoveries that were derived primarily from new classification schemes for cosmic objects and phenomena. By 1920, many such schemes had been formulated that are still in use today. With the help of a spectrograph (which can break up starlight into its component colors the way raindrops break up sunlight into a rainbow), astrophysicists were able to categorize celestial objects not just by their outward appearance but by the detailed features revealed in their spectra. (A well-designed classification scheme, one that might include information obtained from an object's spectrum, can allow profound deductions to be made even if the cause or origin of a phenomenon is not fully understood.)

Among the classifications of the time were three broad categories of objects that proved to be especially relevant to the Shapley–Curtis debate: (1) The stars that are most concentrated along the narrow band of blended light called the Milky Way—by



Seen edge-on, the spiral nebula NGC4565 reveals dark patches along its flattened disk. Heber D. Curtis invoked this typical feature to argue that the Milky Way was one among many such spirals.

Richard S. Perkin Library; American Museum–Hayden Planetarium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then, widely (and correctly) interpreted to be the flattened plane of our galaxy, (2) the hundred or so titanic, globularly shaped star clusters that are slightly more predominant near the plane and are seen in one direction of the sky more than in all others, and (3) the inventory of fuzzy nebulae, including the amorphous varieties, which predominate near the plane, and the spirals, which seem to avoid the plane entirely. Both Shapley and Curtis knew that anything they put forward had to be consistent with these basic observed features of the sky.

If Harlow Shapley could interpret the available data to show that the spiral nebulae were within the bounds of the Milky Way, then there would remain no case for external systems. If Heber Curtis, interpreting the same data, could show that the spiral nebulae were distant island universes, then humanity would be handed the next chapter in its long series of cosmic letdowns.

Shapley's favorite research topic was globular star clusters, so he had much to say about them. Indeed, Shapley is best remembered for his clever and correct suggestion that the center of the system of globular clusters coincides with the center of the galaxy. He reasoned that the observed excess of globular clusters on one side of the sky must reveal the direction, and possibly the distance, to the middle of the Milky Way. This would place the solar system, not in the center, as believed by Curtis and many others, but far out in the plane.

Noting that globular clusters contain abundant stars of nearly all common varieties, Shapley assumed them to be a representative mix of the stars that one might find in the solar neighborhood—stars whose properties and distances were well known. In particular, he assumed that the Cepheid variable stars and the luminous blue stars in the clusters were similar to those found nearby. Using the nearby Cepheids to derive distances to the globular clusters, he obtained anomalously large estimates. Here is how he fit in with other leading astronomers in measuring the distance to a globular cluster called M13 in the constellation Hercules:

Shapley 1915	100,000 light-years
Charlier 1916	170 light-years
Shapley 1917	36,000 light-years
Schouten 1918	4,300 light-years
Lundmark 1920	21,700 light-years

The wildly different estimates of distance to the same cluster demonstrate that astronomers of the day were generally clueless.

Shapley felt strongly that M13, with its 100,000 tightly packed stars, and its (assumed) representative sample of all stars, could be used as a stepping-stone to measure more distant globular clusters and, ultimately, the limits of the galaxy:

According to Shapley,

> The great globular cluster in Hercules [is] a vast sidereal organization. When we accept the view that . . . its stellar phenomena are harmonious with local stellar phenomena—its brightest stars [are] typical giants, its Cepheids [are] comparable with our own then it follows that fainter, smaller globular clusters are still more distant.

By 1920 Shapley had computed the distances to globular clusters beyond M13. Assuming that the outermost clusters delineated the limits of the galaxy, he estimated that the Milky Way was more than 300,000 light-years across. This was far and away the largest estimate ever made for the size of our galaxy.

Curtis did not have the data to refute Shapley's reasoning that the globular clusters contained stars similar to those found in the neighborhood, but he remained cautiously skeptical:

> This assumption [of Shapley's] is a reasonable one, though not necessarily correct, as we have little certain knowledge of galactic regions as distant as five hundred light-years.

He then offered a sharper commentary:

> [Shapley's theory assumes] Cepheids anywhere in the universe have identical [luminosities]. . . . There are many who will regard [this] assumption as a rather drastic one.

But Shapley's confidence was fueled by the work of Henry Norris Russell and Sir Arthur Eddington, two leading theorists of the day who had proffered compelling ideas about the internal structure of stars and stellar evolution. And to reject their ideas, he argued, would be disastrous for astrophysics:

> I believe Russell's illuminative theory of spectral evolution would have to be largely abandoned, and Eddington's brilliant theory of gaseous giant stars would need to be greatly modified or given up entirely.

Curtis was skeptical. Shapley was unlucky. How was Shapley to know that Russell's theory of spectral evolution would eventually be shown to be completely wrong, and that Eddington's theory of gaseous giants would ultimately require serious modification? How was he to know that the nearest high-luminosity blue stars bore little resemblance to the blue stars in globular clusters? And how could he have known that the Cepheid variables in the clusters would later be shown to be a class of stars unto themselves, only a fraction as luminous as he had assumed? These errors of judgment led him to overestimate the distances to all his globular clusters.

Curtis remained convinced that the Milky Way galaxy was much smaller than suggested by Shapley:

> Until more definite evidence to the contrary is available, however, I feel that the evidence for the smaller and commonly accepted galactic dimensions is still stronger; and that the postulated diameter of 300,000 light-years must quite certainly be divided by five, and perhaps by ten.

Who was right? Along most paths from scientific ignorance to scientific knowledge, the correct answer lies somewhere between the extreme estimates that are collected along the way. Such was the case in the great debate: Nowadays, the generally accepted extent of the Milky Way galaxy is 100,000 light-years, about three times Curtis's 30,000, and one-third of Shapley's 300,000 light-years.

Shapley and Curtis now needed to reconcile their ideas about the size of the galaxy with what was known of the spiral nebulae. Estimates of distances to the spirals were more uncertain than those for any other class of object. Shapley was determined to show that they were within the limits of the Milky Way as established by the globular clusters. Both he and Curtis knew that unlike other types of nebulae, which are heavily concentrated near the plane of the Milky Way, the spirals seem to avoid the plane completely. (For this reason, the Milky Way had earned the somewhat spooky title Zone of Avoidance.) They also knew that the typical nebulae near the plane moved relatively slowly, less than sixty miles per second, while typical spiral nebulae had velocities of thousands of miles per second. The fast-moving spirals had to come from somewhere, so Shapley was forced to suggest that the spiral nebulae had somehow been created in the plane of the Milky Way at a regular rate and then ejected from their birthplace.

Curtis remained the skilled skeptic. He wanted to know why spirals had never been observed to form within the plane of the Milky Way and why at least some of the ejected spirals weren't found within

Julie Parcells,
Cancer Patient

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the plane. These were questions to which Shapley had no answer. But Shapley had what he thought was airtight evidence to support his case that the spirals originated within the plane. His close friend and colleague Adriaan van Maanen had analyzed data on several spiral nebulae that were observed to rotate slightly over a period of several years. Van Maanen's measurements implied that the spiral nebulae were actually close enough to allow astronomers to track their rotation. How close must the spiral nebulae be according to Shapley? You guessed it—within about 300,000 light-years. If the spiral nebulae were well outside the Milky Way (and as distant as Curtis would have them), then they would have to be rotating faster than the speed of light.

Unburdened by loyalty to a friend, Curtis could be skeptical about van Maanen's data—after all, no one else had ever detected the rotation of spiral nebulae. Unfortunately for Shapley (and, of course, for van Maanen), later attempts to duplicate these measurements failed, and thus van Maanen's work was ultimately discredited.

Curtis was convinced that the spiral nebulae were the same class of object as the Milky Way galaxy itself. In support of this island universe hypothesis, he argued from directly observable facts:

> The spectrum of the average spiral [nebula] is indistinguishable from that given by a star cluster . . . and in general characteristics resembles closely the integrated spectrum of our Milky Way. It is just such a spectrum as would be expected from vast congeries of stars.

Curtis next noted that spiral nebulae on the sky are oriented at all angles to the viewer. Some are seen face-on while others are seen edge-on, but when seen edge-on, they typically reveal dark, obscuring patches along their plane. Most importantly, and unlike all other classes of objects, their distribution on the sky avoids the Milky Way. All of this was well known and uncontroversial, but Curtis assembled the pieces and scored big with another powerful inference:

> So many edgewise spiral [nebulae] show peripheral rings of occulting matter that this dark ring may well be the rule rather than the exception. If our galaxy, itself a spiral in the island universe theory, possesses such a peripheral ring of occulting matter, this would obliterate the distant spirals [from view] in our galactic plane, and would explain the peculiar apparent distribution of spirals.

At this point, if I had been the moderator, I might have ended the debate, declared Curtis the winner, and sent everybody home, but there was further evidence at hand. Stars in the Milky Way have occasionally been known to appear out of nowhere with tremendous brightness. These new stars were named novae, from the Latin for "new." Such novae had also been observed in several spiral nebulae, including the most famous spiral of them all, the oversized Great Nebula in the constellation Andromeda. Curtis made the assumption that novae form a homogeneous class of objects, which allowed him to draw another powerful inference:

> Correlations between the novae in the spiral [nebulae] and those in our galaxy indicate distances ranging from perhaps 500,000 light-years in the case of the Nebula in Andromeda, to 10,000,000 or more light-years for the more remote spirals. . . . At such distances, these island universes would be of the same order of size as our own galaxy.

Perhaps the most commonly invoked evidence against this interpretation (lodged by Shapley and others of the day) was the anomalously bright nova that appeared in the Andromeda nebula in 1885. If the Andromeda nebula were as distant as Curtis suggested, it would imply that this "super" nova must have had the luminosity of nearly a billion suns—a preposterous thought in 1920. Shapley reasoned that if the spiral nebulae were actually the size of the Milky Way then they must be very distant to appear so small on the sky and "it would be necessary to ascribe impossibly great [luminosities] to the new stars." Only later would the community of astrophysicists learn of a variety of nova that indeed reaches the luminosity of a billion suns. What do we call them? Supernovae, of course.

Even though Shapley discounted the spiral nebulae as island universes, he no doubt wanted to appear open-minded. In his summary statement, which reads like a disclaimer, he entertained the possibility of other worlds:

> But even if spirals fail as galactic systems, there may be elsewhere in space stellar systems equal to or greater than ours—as yet unrecognized and possibly quite beyond the power of existing optical devices and present measuring scales.

And Curtis openly conceded that Shapley might be on to something with his hypothesis that spiral nebulae were ejected, given that they were moving away at high speeds. In his concession, Curtis simultaneously (yet unwittingly) presaged to the world that we live in an expanding universe by noting that, "The repulsion theory, it is true, is given some support by the fact that most of the spirals observed to date are receding from us."

Curtis's views were ultimately shown to be closer to the truth than Shapley's, in spite of what you might infer from their relative career paths after the debate. By the end of the 1920s, not only was the island universe theory vindicated (by better and more abundant data from Edwin Hubble on distances to spiral nebulae), but the universe was revealed to be expanding in a manner consistent with the predictions of Albert Einstein's General Theory of Relativity, published just a few years before in 1916. Einstein, by the way, attended the Shapley–Curtis debate.

Today, what we need are more of these debates. This would allow the community of scientists to share with the public those turbulent paths that lead to scientific discovery—paths that reveal science, not at its worst, but at its best.

To commemorate the seventy-fifth anniversary of the Shapley–Curtis event, a debate will be held this spring in the same Smithsonian auditorium to air views on whether gamma ray bursts owe their mysterious origin to events within the Milky Way or outside of it. Gamma ray bursts are short bursts of high-energy radiation that are detected in all directions in the sky. Unable to reach Earth's surface owing to our protective blanket of atmosphere, all bursts have been measured by specially designed spaceborne satellites. The growing catalog of gamma ray bursts—more than a thousand have been profiled—reveals wild variation in both intensity and duration, yet their distance and cause are almost as much a mystery today as when the first burst was discovered in 1969. While not as sexy a topic as the existence of island universes, the debate is no less interesting as a modern exercise in wha defines the belief systems of opposing parties in the face of inconclusive data.

Defending the idea that gamma ra bursts are cosmological in origin is Bohdan Paczyński, a colleague of mine from Princeton's Department of Astrophysica Sciences. The "opposing" view will be defended by Donald Q. Lamb, of the University of Chicago's Department of Astronomy. Paczyński's core argument is that th gamma ray bursts are sufficiently scattered on the sky to support the claim tha they do not arise from the flattened disk o our own Milky Way galaxy. A commo rebuttal is that we know of no phenome

on as energetic as a gamma ray burst at
alactic distances. In other words, the in-
nsities of some bursts as measured on
arth are so high that if they really are at
osmological distances, they must be
ind-bogglingly luminous—even by as-
onomical standards.

If the Milky Way itself hosts all gamma
y bursts, then their luminosities would
e manageably low, allowing us to invent
any plausible mechanisms as a cause.
ut if you ask me, the case against a cos-
ological origin sounds suspiciously like
at offered by Shapley seventy-five years
go, when he noted the "impossibly great"
minosities of "new" stars in the spiral
ebulae.

Many astrophysicists have already
ken sides (if you are wondering, I am in
e cosmological camp), and at least one
as gone beyond the debate: One astro-
hysicist I know described some conse-
uences for life on Earth if gamma ray
ursts are cosmological. If they occur in
alaxies, then the Milky Way may have
layed host to many of these high-lumi-
osity events. The result? If such a gamma
y burst had occurred nearby, then the im-
ulse of high-energy radiation would have
estroyed the ozone layer, allowed ultravi-
let radiation from the sun to reach Earth's
urface, and then knocked out the base of
e food chain. Chalk up another imagina-
ve idea for the mass extinctions in the ge-
logical record.

Ultimately, our understanding of the
niverse will not depend on who argues
e best, the loudest, or the most elegantly.
e will always want more data, which is
o less true today than in 1920, when Cur-
s wisely noted in his summary, "There
re many points of difficulty in either the-
ry of galactic dimensions, and it is doubt-
ss true that many will prefer to suspend
dgment until much additional evidence
forthcoming."

Many people alive today were born be-
re the great debate of April 26, 1920.
uring their lifetimes, as more data be-
ame available, we confirmed that the
ilky Way galaxy, with its hundred bil-
on stars, is just one of a hundred billion
alaxies—island universes scattered out
the farthest reaches of space. For me,
is simple fact in the accumulated knowl-
dge of human discovery bursts forth as
e most profound of them all.

*eil de Grasse Tyson is an astrophysicist
ith a joint appointment at the American
useum–Hayden Planetarium and
rinceton University.*

CELESTIAL EVENTS

by Joe Rao

In July 1610, when Galileo first pointed his telescope at Saturn, he saw only a blurry image of the planet, magnified some thirty-two times. Because he couldn't make out the rings clearly, he thought that Saturn was a triple body—two small planets flanking a large one. "They are like two servants who help old Saturn on his way, and always remain at his side." When he observed Saturn again in December 1612, he was startled to see that the two small companions were gone. "Has Saturn indeed swallowed its children?" he asked. (Saturn, after all, is the Roman equivalent of the Greek Kronos, who, myth has it, swallowed his children to keep any from growing up and overthrowing him.) Later Galileo found that Saturn's two escorts had reappeared.

Galileo began to think that the lenses of his telescope had deceived him. Discouraged and lamenting that his mind was too weak to comprehend the phenomenon, he died in 1642, never knowing the true nature of what he had observed. With a better telescope, he would have been able to tell that the two smaller "planets" were really tilted rings encircling Saturn. As the planet's orientation changed, the rings turned edge-on to earth-bound viewers, so Galileo would have seen them disappear.

With better optics, a Dutchman named Christian Huygens announced in 1656 that Saturn was "girdled by a thin flat ring, nowhere touching." In our own time, *Voyager* revealed the 171,000-mile-wide ring system in great detail, confirming that it is composed of countless individual particles—largely water ice—that range in size from microscopic specks to flying mountains a couple of miles across. The rings look solid to us because the whole swarm of satellites orbits Saturn in a disk that is, on average, less than five hundred feet thick.

Twice during the nearly thirty-year period that Saturn takes to orbit the sun, its rings align so that we see them edge-on. For the past seven years, the ring system, as seen by us, has been growing narrower; as they did back in 1612, the rings will narrow to nothing this month on May 22d. (Even the most powerful telescope will not be able to discern them.) From then until August 10, we'll be facing the unilluminated south side of the rings, perceptible only through the largest of telescopes. The illuminated north side will then tip slightly toward us, and we will see a narrow thread of light bisecting Saturn's disk.

On November 19, the sun will cease to shine on the north side of the rings, and they will again be extremely difficult to detect. By February 11, 1996, the rings will again be edge-on to Earth, and finally we will see more and more of the illuminated south side. Until 2003, the rings will appear to widen, providing an ever enlarging screen to reflect sunlight and making Saturn the ringed beauty we have all come to know.

THE PLANETS IN MAY

Mercury is low in the west–northwest soon after sunset at the beginning of the month. On the 1st, look for the innermost planet 13 degrees to the lower right of Aldebaran and 8 degrees to the lower right of a thin crescent moon. From the 4th through the 14th, Mercury will not set until after twilight has ended, making this an excellent time to look for this elusive planet. It will reach its greatest elongation—21.6 degrees from the sun—on the 12th. By the third week of May, it will fade considerably as it moves rapidly back toward the sun.

Venus is still a glittering "morning star" rising in the dawn, roughly at 4:30 A.M., local daylight time. Although it does not rise very high before sunup, Venus shines brightly at magnitude –3.9. The planet will be roughly two moon diameters above, and to the right of, a thin crescent moon on the morning of the 27th.

Mars continues to fade as its distance from Earth increases. On the 1st, it does not set until about 3:00 A.M., local daylight time, but by the end of the month, Mars will be setting about ninety minutes earlier and will be some 24 million miles farther away. On the 24th, Mars will have its third and final conjunction with Regulus, the brightest star of Leo, the Lion. Mars, appearing slightly brighter than Regulus will pass a degree to the north.

Jupiter shines brightly at magnitude –2.5 and rises in the southeast within two and a half hours of sunset on the 1st. By the 31st, the planet rises almost with sunset. It will be near, and to the right of, the nearly full moon on the night of the May 15–16.

Saturn is in Aquarius and rises out of the southeast about three hours before the sun. It fades this month to magnitude 1.3—appreciably dimmer than usual because on the 22d its rings will appear edge-on. Saturn is below and to the right of the fat crescent moon on the morning of the 23d.

The **Moon** is at first quarter on the 7th at 5:44 P.M., EDT; full moon is on the 14th at 4:48 P.M., EDT; last quarter is on the 21st at 7:36 A.M., EDT; and new moon is on the 29th at 5:27 A.M., EDT.

Joe Rao is a meteorologist and a guest lecturer at the American Museum–Hayden Planetarium.

Schooner Cove, Labrador

by Robert H. Mohlenbrock

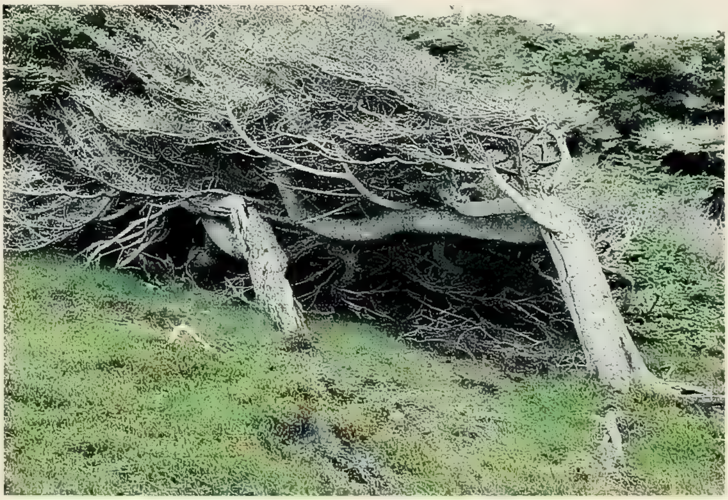
Separated by the ten-mile-wide Strait of Belle Isle, Newfoundland Island and mainland Labrador together make up Canada's province of Newfoundland. The fifty-mile stretch of the Labrador coast that parallels the strait, from the border with Quebec eastward to the village of Red Bay (Whaling Capital of the World, 1550–1600), is known as Labrador Straits. This sparsely populated region, with barely 3,000 permanent residents, consists of secluded coves, massive headlands, and small villages connected by a single paved highway. Labrador Straits is most easily reached by ferry from Saint Barbe, Newfoundland, or by air. It offers excellent fishing, as well as bird and whale watching, hiking, camping, and sea kayaking. Determined explorers can venture into the hinterland on their own, or with the assistance of local outfitters.

The granite rocks exposed on the headlands near Red Bay are some of the oldest in North America, dating back one billion years. Other rocks along Labrador Straits—sandstone, shale, and dolomite—are half that age. A rocky reef just east of Pointe Amour lighthouse is one of the few places in the world with fossilized sponges. Apart from these geological attractions, the coast presents a variety of plant communities, which visitors may sample by hiking along three trails developed and maintained by the Labrador Straits Historical Development Corporation. One of these is the Schooner Cove Trail, which begins from the paved highway a short distance west of the village of L'Anse-au-Loup.

Approximately three miles long, the trail climbs across the nearby headland before gradually sloping down to the water's edge along the Strait of Belle Isle. The headland, sandy in most places, pebbly in others, also has boggy spots where underground water seeps from the rock. Most of it consists of areas of low-growing, flowering plants. Referred to by the locals as barrens, these habitats may be dry or wet. The dry barrens support lichens and a limited variety of flowering plants, while the wet barrens, kept moist from continuous underground seeps, boast a thick cover of spongy peat moss, as well as an abundance of flowering species. In the wettest areas there are pools of clear water, up to one foot deep, around which grow several kinds of sedges, including one with pure white plumes known as cotton grass.

On my visit, during the second week of August, the most conspicuous plant of the wet barrens was the bakeapple. Usually called cloudberries in other parts of North America, bakeapples are related to blackberries and raspberries. One inch in diameter, the fruits are shaped like blackberries but are red or, when ripe, a translucent orange color. The melt-in-your-mouth ripe fruits draw many of the local populace, who pick them for home use and for sale. Each year, a four-day bakeapple folk festival takes place near the picturesque Pointe Amour lighthouse. Here the bakeapples may be sampled in a variety of delightful treats, and a jar of bakeapple jelly makes a great souvenir.

Growing with the bakeapple are a number of other berry-forming plants, such as partridgeberry (harvested later and made into jam, jelly, muffins, and pies), crackerberry (from a type of dwarf dogwood that is only four inches tall), dwarf blueberry, bearberry, and crowberry (whose narrow leaves look like miniature spruce needles). Other common plants in the wet barrens include Labrador tea, bog rosemary, and snowberry, three members of the heath family. An inconspicuous plant is moss campion, which looks like a tiny moss but sends up an inch-tall stalk with a small, five-petaled flower.



Near Schooner Cove, black spruce and other trees form a stunted forest known as tuckamore. Opposite page: The Pinware River.

Robert McCaw

In addition to the barrens several patches of tuckamore forest dot the headland. "Tuckamore" is a term used in arctic and boreal regions to refer to dense stands of stunted, gnarly trees, mostly spruces. In Labrador Straits, these areas are dominated by black spruce, but include white

spruce, speckled alder, larch, and other species. The trees, at most eight feet tall, have been stunted and twisted by the constant salt spray that blows in from the strait. Where the salt spray is heaviest, the black spruces are no more than one or two feet tall and look like flat-topped shrubs. Their trunks, however, are as much as six inches in diameter at the base, showing that the trees are quite old.

The salt spray does not deter the wildflowers and ferns that grow in the tuckamore understory. These include wild lily-of-the-valley, dwarf false Solomon's seal, blue aster, alpine meadow rue, and several kinds of sedges. Among the ferns are the delicate oak fern and the coarser lady fern and spinulose woods fern.

Schooner Cove

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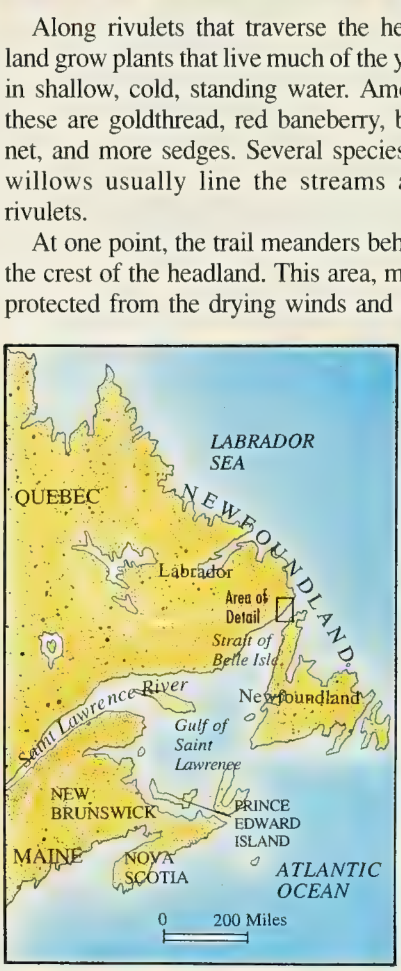
Along rivulets that traverse the headland grow plants that live much of the year in shallow, cold, standing water. Among these are goldthread, red baneberry, burnet, and more sedges. Several species of willows usually line the streams and rivulets.

At one point, the trail meanders behind the crest of the headland. This area, more protected from the drying winds and salt spray, consists of a lush green meadow dominated by grasses and robust flowering plants. Reed grass is the most abundant plant, but it is overtopped by tw large members of the carrot family. One i cow parsnip, with foot-wide, flat-toppe clusters of tiny white flowers and large much divided leaves. The other is angelica, or alexanders, whose tiny white flowers are arranged in perfectly spherica



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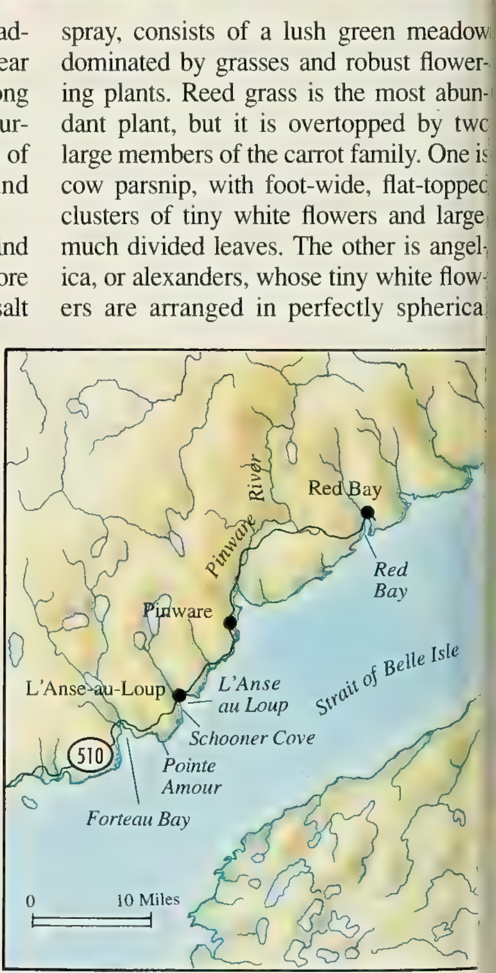

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0
10 Miles

Joe LeMonni

ohn Eastcott:Yva Momatiuk

warf birch branches, left, lie pon a carpet of lichen. Below: A akeapple is ripe for picking.

red Bruemmer

eads as much as six inches in diameter. ts leaves are also repeatedly divided, but vith smaller segments than in the cow arsley.

Where the carpet of grass is not so hick, more delicate wildflowers may pring up. Showiest of these are a purple-purred gentian, a ladies'-tresses orchid, nd starflower. All are widespread in the orthern United States and Canada. There s also a tasty dwarf dewberry that ripens a ew days after the bakeapple.

Eventually the trail reaches the sandy horeline of Schooner Cove. Protected by deep indentation in the coastline, the ove was first occupied by paleo-Indians bout 9,000 years ago, shortly after the re-reat of the last ice age glaciers. A French ishing port in the early 1700s, it was taken ver by the British in 1763. Later it was illed every summer with fishing chooners. About 100 years ago, the cove ven harbored a whaling factory. Today it erves only as a mooring place for recre-ational boats.

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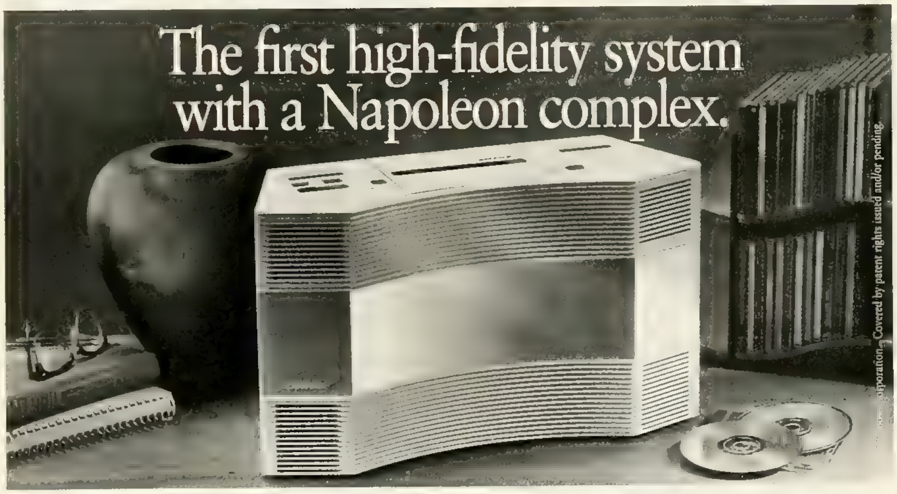
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Bumpy Ride

by Anthony F. Aveni

Most cosmologies are stories that seek to explain our human origins. For the ancient Maya of Mesoamerica, brave hero twins journeyed through the underworld, battling the archaic gods of disease and pestilence, boastfulness and pride, in order to clear the way for the dawn that would see the birth of the human race. In Babylonian mythology, Marduk won authority over the other gods by battling the monstrous Tiamat; he then set to work organizing the universe, assigning dwelling places to the gods, fixing the course of the heavenly bodies, and creating humans. In the biblical account of Genesis, God created heaven, earth, and all that they contain, and then gave human beings dominion over nature.

The story line of modern cosmology has less to do with us. Covering a far wider turf and a much bigger time span, it goes likes this: what happened in a few cataclysmic moments, billions of years ago, predestined what the universe is today and what it will be in the future. *Voyage to the Great Attractor* is one exciting chapter in our efforts to read the cosmic script. Told by Alan Dressler, an astronomer at the Carnegie Institution observatories in Pasadena, California, this is the very human story of the dramatic discovery that our galaxy, the Milky Way, and everything around it is streaking toward a very remote point in the constellation Centaurus.

In the twelve billion years since the big bang, the expansion of the universe hasn't been gradual or smooth. Cosmic ripples that formed in the explosion's aftermath coalesced over time into gargantuan gobs of invisible dark matter that tug at us and move us eccentrically. As a result, our galaxy is on a cosmic roller coaster ride toward one of these distant gravitational mountains of dark and scarcely visible matter called the Great Attractor.

Voyage chronicles this big-science discovery step by step, warts and all. Dressler first introduces the six other astronomers on his multitalented research team: Sandy Faber, of the University of California's Lick Observatory in Santa Cruz, the oft physically disabled, courageous mentor of the group, who struggled to find her niche as a woman in a scientific profession; Roger Davies, who came from Cambridge University to study elliptical galaxies under Faber at Santa Cruz; Roberto Terlevich, a young Argentine who did his Ph.D. work on elliptical galaxies; Dave Burstein, of Arizona State University, the temperamental perfectionist, able to perform incredible feats of memory, who manned the equipment that analyzed galaxy brightness; Donald Lynden-Bell, the brilliant Cambridge theorist, whose frequent and heated arguments with some of the more experimentally oriented members of the group polarized ideas about the theoretical models built from the data; and Gary Wegner, of Dartmouth College, who was the last to join and whose instrumentational skills were to prove invaluable.

VOYAGE TO THE GREAT ATTRACTOR: EXPLORING INTERGALACTIC SPACE, by Alan Dressler; *Alfred A. Knopf, 1994; 355 pp., illus.*

These astronomers are trying to understand what happens on a vast scale. Yet what has always amazed me about the field is that to understand what happens on such a big scale, we astronomers are forced to study the microscopic structure of matter. In this respect, we suffer a major disadvantage. Biologists dissect microorganisms, and geologists slice up rocks, but all we have with which to test our ideas are photons—particles beamed from distant sources across the vast reaches of space, which are caught in the tube of a telescope or collected by a radio dish. This is high-tech astronomy. Dressler's team didn't unmask the Great Attractor by pressing eye to telescope but by using very sophisticated detectors.

In their research, a light beam was sorted into the colors of the spectrum, and photons of different wavelengths were amplified and converted into electrical signals that were stored in a computer. The emerging patterns generated from the data revealed both the chemical elements (such as calcium, magnesium, hydrogen, helium) and the ambient conditions of the glowing matter (the source of those photons that have spent the past several billion years getting to us).

These spectral images were of elliptical galaxies, the really giant candles that illuminate the intergalactic temple. Ellipticals are structurally simpler than most other denizens of deep space, such as spiral galaxies, whose spherical and disklike shapes are composed of billions of stars, many of which are still forming. Ellipticals are smooth and roundish; their stars were born relatively early in the history of the universe, and few new stars are appearing. Because ellipticals are structurally simple, Dressler's team (later

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termed the Seven Samurai by the press) chose them as reference points in mapping out the distribution and motion of matter in the distant reaches of space.

To help get across otherwise extremely difficult and complex concepts to the lay reader, Dressler wisely relies on analogy, which I, as an astronomy teacher, particularly appreciated. He explains the correlation between a person's height and body weight to elucidate how the "bulk" of an elliptical galaxy is calculated. To explain how astronomers determine the distance of galaxies by measuring their size and brightness, he cites how we commonly estimate the distance of neighboring houses by judging the apparent heights of people seen within.

Since Edwin Hubble's work in the 1920s, we've known that the universe is expanding, because the farther out we look into space, the faster all galaxies seem to be moving away from us. We measure the recessional velocity of distant galaxies by their red shifts—the movement of their light toward shorter frequencies or longer wavelengths (redder colors) as they recede from view. (Sound waves are a good analogy—think of the high-pitched sound of an approaching train whistle, which suddenly descends to a lower pitch as the train rumbles past us.)

What the Seven Samurai succeeded in demonstrating is that the recessional motion of ellipticals isn't quite the same in all directions. Looking at these galaxies statistically, they found that ellipticals have a "peculiar velocity"—an extra motion added on to the universal expansion. To understand what this means, imagine driving on the highway at fifty-five miles per hour and being passed continually by cars doing an average of sixty miles per hour. We could say that there is a drift motion to the flow of traffic that is five miles per hour faster than we ourselves are going. That, Dressler argues, is something like what's happening to our galaxy.

What causes the peculiar velocity of the ellipticals? The Dressler team attributes it to a mysterious gravitational pull from afar. We (and everything within 100 million light-years of us) are in the midst of a river of matter that is plummeting at 400 miles per second toward a cosmic stream in the direction of the Hydra-Centaurus supercluster of galaxies. Based on the magnitude of the peculiar motion of the ellipticals, this supercluster, they calculate, is rather large—approximately a million times the mass of our Milky Way galaxy and 500 million light-years in extent.

Initially, when the Great Attractor model was first conceived more than a decade ago, Dressler and his group were skeptical of their own conclusions, as were most mainstream astronomers. For curiosity's sake, however, I made a quick survey of contemporary college-level astronomy texts and found that most astronomers have now yielded to the idea that we really do live in a bumpy-lumpy universe with a number of attractors tugging at us from different directions.

If this is the universe now, then what vill happen to us in the future? Like many cientists at the end of the millennium, ressler questions how we acquire and ise knowledge. He is certain that however ielpless and insignificant we might all feel n the face of the chaotic big bang, scienific understanding will nonetheless lead is out of our predicament. If we believe ressler, we should keep the faith in scince. Up until now, material resources, nanaged and manipulated by science and echnology, have provided us with the ighest quality of life ever. Dressler sees ur present era as a phase "that germinated ome 2,500 years ago, blossomed within he last 400 years, and will come to ruition . . . a maturation of scientific eneavor over the next few centuries."

In Dressler's scenario of the future, we vill genetically engineer versions of prooplasm, or sentient "descendants," with ie capacity to outperform us. They might ven evolve into higher life forms themelves. Computers, which today are often haracterized in evolutionary terms, will ecome increasingly intelligent and, acording to Dressler, will unite with us to roduce part-human, part-machine neocientists ("I married a teen-age comuter"?). As colonists of the future, we vill ultimately be able to ride the cosmic xpress train toward every conceivable rop-off point in the firmament.

Does this scenario parallel the end of istory or the end of nature? The author imself admits that he believes the end of umanity is preordained. But perhaps by iat time, the universe will have "invented way to know itself." Right now, however, we can begin to understand the naıre of the universe by realizing that the ew complexity (in whose creation we articipate) ought to be embraced rather ian avoided. The discovery of the Great ttractor, that mountain of unseen mass iat Dressler and his colleagues so skillılly succeed in convincing us is really out iere, is but one testament to our being all iat we can be—or so claims this book. ut what would Newton have thought, or or that matter, the ancient Maya or Babymians?

nthony F. Aveni is Russell B. Colgate rofessor of Astronomy and Anthropology t Colgate University. He is the author of onversing With the Planets: How Science and Myth Invented the Cosmos *and* mpires of Time: Calendars, Clocks and ultures, *both published in paperback by odansha.*

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Naturalists and Artists at the Zoological Society of London

Scientific prints published in the London Zoological Society's *Proceedings* and *Transactions* will be on display in the Library Gallery beginning Monday, May 1. The exhibition will feature the works of such outstanding natural history artists of the mid-nineteenth century as Joseph Wolf, Edward Lear, John Gould, Joseph Smit, and John Keulemans, all of whom used the newly developed technique of lithography to illustrate scientific papers. In addition to these rarely seen illustrations, the history of the Zoological Society and biographical sketches of scientists and artists will be part of the exhibition.

The Double-edged Helix

Because of well-publicized advances in genetic research, many ideas about genes have been incorporated into popular culture, shaping social ideologies and institutional agendas. On Tuesday, May 2, at 7:00 P.M., Dorothy Nelkin, a sociology professor at New York University and author (with historian Susan Lindee) of *The DNA Mystique: The Gene as a Cultural Icon*, will discuss aspects of this phenomenon. Tickets are $12. For more information, call (212) 769-5310.

The Jews of Yemen

In the fourth of her series of ethnographic films about Middle Eastern and Indian populations of Jews, Johanna Spector will examine the customs and ceremonies of an enclave of Yemenite Jews in Israel, whose music, architecture, rituals, and dance are much as they were before the group emigrated from Yemen in 1948. This program will be held in the Main Auditorium on Tuesday, May 30, at 7:00 P.M. Call (212) 769-5606 for ticket availability.

Spider Webs

The intricate nature of spider webs will be the subject of two talks on consecutive Wednesday evenings at 7:00 P.M. On May 3, William A. Shear, of Hampden-Sydney College in Virginia, will give an evolutionary view of web variation and levels of complexity. On May 10, Brent Opell, of Virginia Technical University, will discuss thread thickness and its association with web architecture. Tickets for both evenings are $20 (or $12 for each lecture). Call (212) 769-5310 for more information.

In the Footsteps of Roy Chapman Andrews

Since 1990, the American Museum and the Mongolian Academy of Sciences have collaborated on exploring the Gobi's rich fossil beds. Malcolm McKenna, Frick Curator of Fossil Mammals at the Museum, and his wife, Priscilla McKenna, will give a firsthand account of these Gobi expeditions on Thursday, May 4, at 7:00 P.M. in the Kaufmann Theater. For more information, call (212) 769-5606.

Wonders of New York Fossils

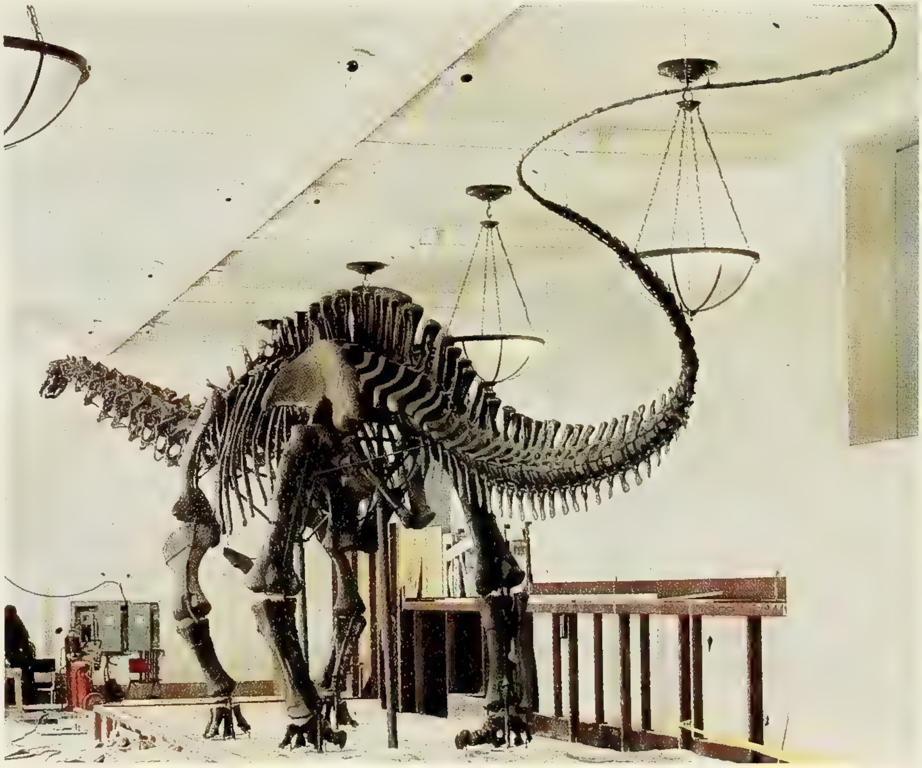
A large variety of fossils can be found in the geological strata underlying metropolitan New York, as well as in the stone brought in and used in many of the city's buildings. On two consecutive Tuesdays, May 2 and 9, New York's fossil trove will be the subject of slide-illustrated lectures by Sidney S. Horenstein, geologist and coordinator of environmental public programs at the Museum. The program will be presented at 7:00 P.M. in the Kaufmann Theater. Tickets for the series are $20 ($12 each lecture). Call (212) 769-5310 for information.

Seismosaurus: The Earth Shaker

Found in New Mexico's Morrison Formation, *Seismosaurus hallorum* is the newest and largest Mesozoic dinosaur ever discovered. David Gillette, formerly the *Seismosaurus* project coordinator and now state paleontologist of Utah, will talk about this 100-ton, 150-foot-long sauropod on Wednesday, May 24, at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for more information.

Celestial Fireworks

A slide-illustrated talk, "Exploding Stars—Celestial Fireworks," will be presented by Alex Filippenko, a professor of astronomy at the University of California at Berkeley, on Monday, May 8, at 7:30 P.M. This talk is part of the "Frontiers in Astronomy and Astrophysics" series



The Museum's Apatosaurus *skeleton stands in the unfinished Hall of Saurischian Dinosaurs. Two new dinosaur halls will reopen on June 2.*

Blackwell/Finnin

and tickets are $8 ($6 for members). Call (212) 769-5900 for information about this and other Planetarium events, including the Sky Show “The Ten Most Asked Questions About the Universe” and the exhibition of Hubble Space Telescope discoveries.

SEXUAL LEGACIES

How ancient notions of gender influence our lives in the office and at home will be the subject of a talk by Helen Fisher, a research associate in the Department of Anthropology at Rutgers University. Based on her most recent book, *Anatomy of Love: A Natural History of Mating, Marriage, and Why We Stray*, her lecture will take place at 7:00 P.M. on Thursday, May 11, in the Main Auditorium. For ticket availability and information, call (212) 769-5606.

THE DAY BEFORE AMERICA

The transformation of the North American continent over the past 18,000 years, including the role of climate and human activity in shaping the world we have inherited, will be the subject of a talk on Monday, May 8, at 7:00 P.M. by editor and author William H. MacLeish. His lecture will be adapted from his recent book, *The Day Before America: Changing the Nature of a Continent*. Tickets are $12. For information, call (212) 769-5310.

WORLD MYTHS AND RELIGIONS

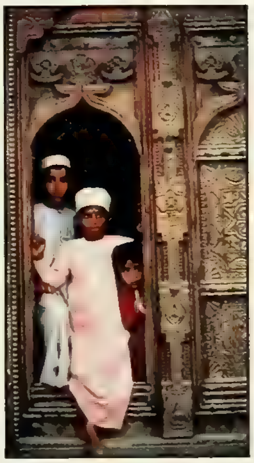
On Saturday, May 6, the Education Department will offer two free programs on Russian culture as part of the year-long series “Unity Through Diversity.” At 6:30 P.M. in the Hall of Ocean Life, twenty-seven dancers, singers, and musicians wearing traditional dress will demonstrate the diversity of Russian folk traditions from three regions—Voronezh, northern Arkangel, and Lake Baikal. At 8:00 P.M. in the Kaufmann Theater, scholars will compare and contrast the cultural and spiritual beliefs of these three areas of Russia. For a schedule of additional programs in May that explore world myths and religions, call (212) 769-5315.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

American Museum of Natural History

ARABIAN GULF VOYAGE

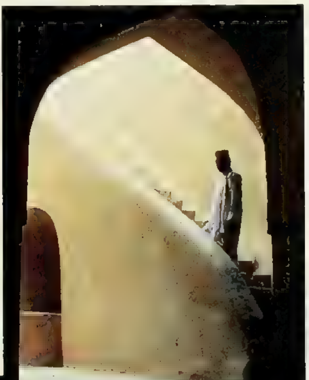
December 3-18, 1995



LYNN SIMARSKI/ARAMCO WORLD

The Arabian Peninsula, inhabited for at least 5,000 years, has seen the rise and fall of great kingdoms, the expansion of vast trade routes and the spread of Islam throughout the region. More recently, the oil boom of the last several decades has brought monumental changes to the countries of the Arabian Peninsula, transforming small villages and ancient towns into sleek, modern cities. Yet despite Arabia's profound influence on world history, many of the Arabian Gulf States are virtually unknown to outsiders.

This December, a team of lecturers from the American Museum of Natural History will lead an exciting cruise to the ancient and little-known countries of Kuwait, Bahrain, Qatar, the United Arab Emirates and Oman. From modern Kuwait City to the ancient trading center of Muscat, we will experience the ways of centuries-old nomadic tribal life existing alongside the spectacularly transforming affluence of the modern oil boom. In between, we will visit ancient and modern cities, desert villages and archeological sites. Join us for this unusual opportunity.



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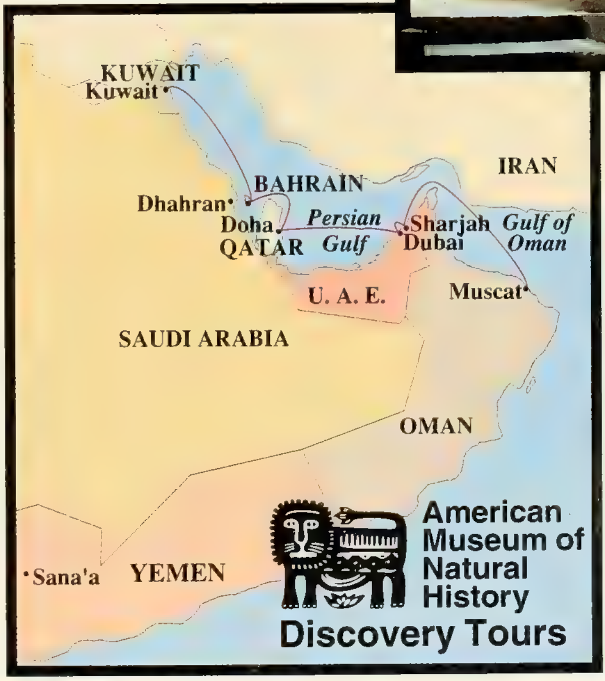

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THE NATURAL MOMENT

Red Suspenders

Photograph by Konrad Wothe

Drinking while upside down is no problem for this female orangutan, suspended over a river in northern Sumatra's Gunang Leuser National Park. (Hanging from a neighboring vine, her nearly independent youngster, not shown, was scooping river water with its hands.) These arboreal apes normally find all the water they need in the rain forest trees, where raindrops from frequent downpours collect in holes. The animals have also been observed licking rainwater from leaves and from the hair of their drenched forelimbs.

Orangutans rarely descend to the ground, spending the nights in temporary nests in the treetops. During the day, their flexible joints, combined with powerful, hooklike feet and hands, allow orangutans to roam the rain forest canopy in search of fruit, their primary food. The efficiency of the routes orangutans take in their quest suggests an uncanny ability to remember the location and season of individual fruit-bearing trees. Rather than leaping from branch to branch like the acrobatic gibbons, these apes have a more mellow approach to bridging gaps between trees: they use their weight to swing small trees and branches back and forth until they can simply reach across the void. When feeding, orangutans distribute their weight among several small branches and lianas, no one of which alone could support them—and thereby can reach ripe durians, figs, lychees, and young leaf shoots that would otherwise be off limits.—*R.A.*

American Museum of Natural History

CHRISTMAS IN THE
CARIBBEAN
DECEMBER 23-31, 1995

With rain forests, volcanoes, caverns, charming towns, historic sites, exquisite beaches and spectacular coral reefs, the islands of the Lesser Antilles in the Caribbean offer endless diversity of landscape, wildlife and culture. This winter the American Museum of Natural History will lead a special cruise aboard the elegant, 4-masted tall ship, *Star Clipper,* to explore Barbados, Tobago, Grenada, Carriacou, Bequia and Martinique. Join us for an enchanting tropical holiday among islands draped with verdant vegetation and teeming with exotic wildlife. Affordably priced from $1,525 per person for the whole family.

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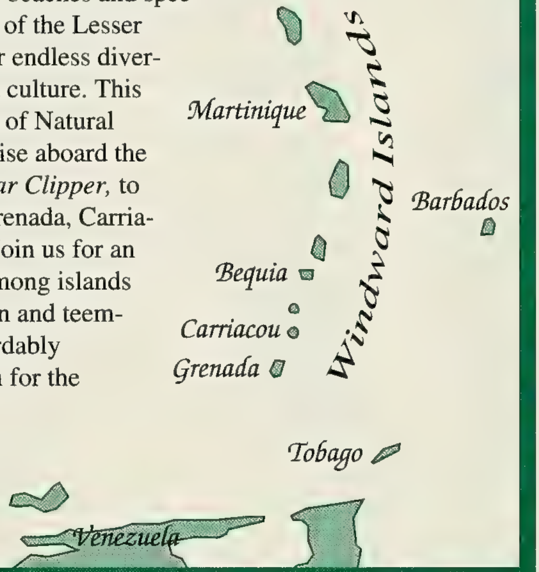

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AUTHORS

Jean Clottes (page 30) is scientific adviser for prehistoric rock art studies at the French Ministry of Culture and chairman of the International Committee for Rock Art. An archeologist by training, Clottes served for twenty-one years as director of prehistoric antiquities for the Midi-Pyrénées region, where he studied and helped to conserve the painted caves. His current research involves the application of new laboratory techniques for analyzing ancient art; he is also interested in other archeological evidence that may throw light on the artists' motivations, technology, and culture. Last year *Natural History* published his description of the Cosquer Cave, a half-submerged grotto near Marseille that contains depictions of auks and sea creatures. The Cosquer discovery of a year ago was topped last December by an even more spectacular find in southeastern France: the Chauvet Cave. Clottes's article about this hitherto unknown gallery of remarkable Ice Age

While observing migrant monarch butterflies on the southwestern coast of Louisiana, **Gary Noel Ross** (page 36) became intrigued with the region's

SAVE THE RAINFOREST

rt is the only account he has written in nglish. For further reading on painted aves, Clottes recommends *Paleolithic ave Art*, by P. Ucko and A. Rosenfeld London: World University Library, 1967) and *Images of the Ice Age*, by Paul . Bahn (New York: Facts on File, 1989).

heniers, fragmented patches of terra irma in an otherwise marshy territory. The falcate orangetip butterfly, whose life ycle he documents in this issue, is just ne of the organisms that depend on this ragile habitat. Professor emeritus of iology at Southern University, Ross is ducational programming consultant for he new "Butterflies in Flight" exhibit at he Audubon Zoo in New Orleans. He is lso the author of two recent publications, *ardening for Butterflies in Louisiana* nd *Everything You Ever Wanted to now About Butterflies: 100+ Questions nd Answers*. For additional reading, he ecommends *Butterflies East of the Great lains: An Illustrated Natural History*, by aul A. Opler and George O. Krizek Baltimore: Johns Hopkins, 1984), and *he Butterflies of North America: A atural History and Field Guide*, by ames A. Scott (Stanford: Stanford niversity Press, 1986).

American Museum of Natural History

ANTARCTICA

January 30 - February 18, 1996

Cook, Amundsen, Byrd, Larsen, Nordenskjold, Shackleton, Scott, Ellsworth—these are just a few of the many great explorers who were lured to Antarctica in the past by its beauty, isolation and grandeur. In this same spirit of exploration, a team of lecturers from the American Museum of Natural History will lead a voyage aboard the *World Discoverer* this winter for an exploration of several subantarctic islands and the Antarctica Peninsula.

Sailing among the icebergs the Antarctic Peninsula's spectacularly beautiful channels, we will search for whales and make expedition stops to visit penguin rookeries and scientific bases. We will also visit the magnificently mountainous island of South Georgia, which teems with fur seals, elephant seals, penguins and albatross. Along with the rugged, barren South Orkney Islands and the wind-swept Falkland Islands, these subantarctic islands offer unsurpassed opportunities to observe a wide range of seabirds and marine mammals up close. Join us for a voyage to the least-known and most remote place on the planet.

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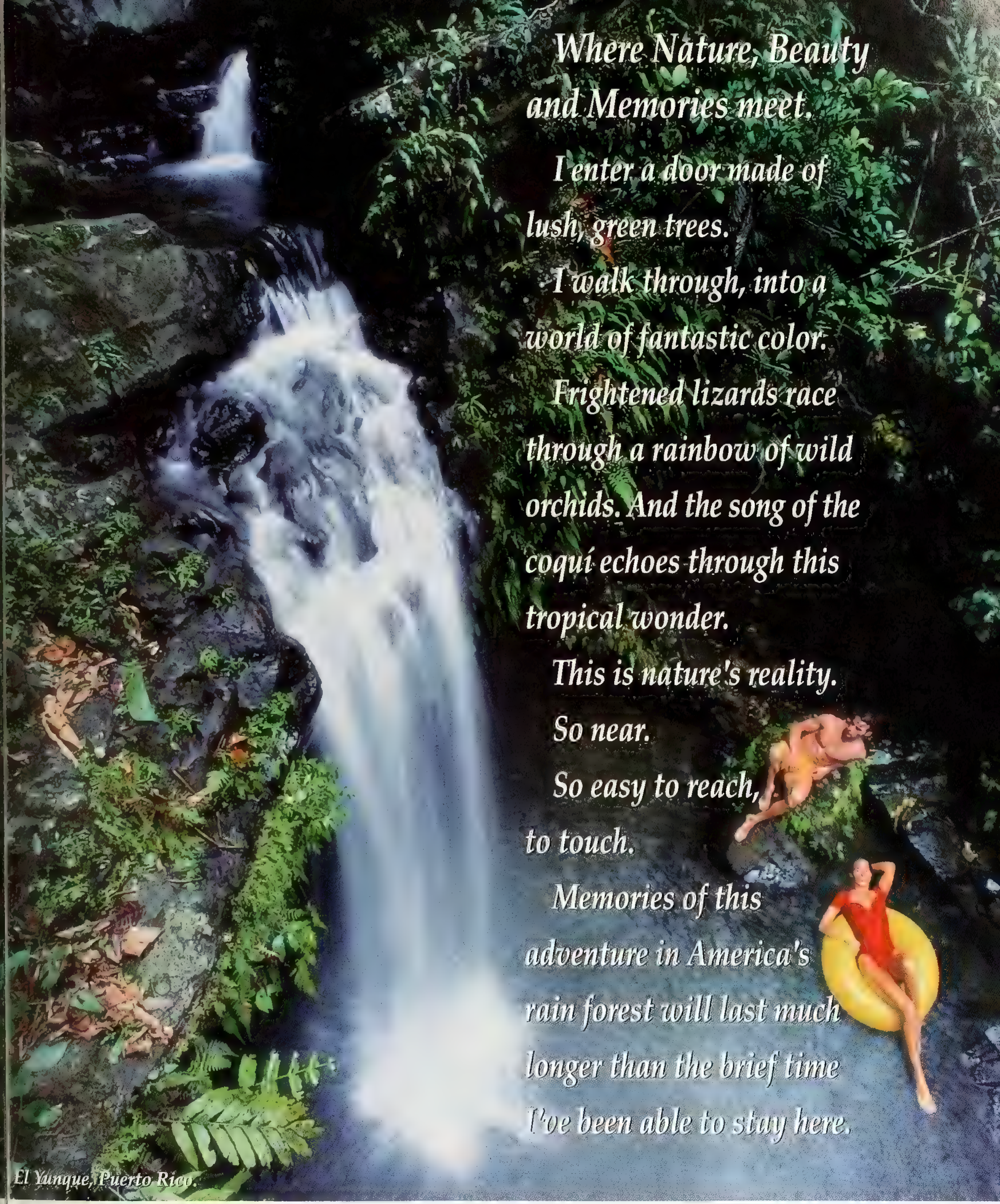
When **Hans Klingel** (page 46) began his scientific career, hippos were definitely not on his short list of animals to study. After writing his Ph.D. dissertation on centipedes, he then conducted fieldwork on the behavioral ecology of whip scorpions and whip spiders in Southeast Asia, where he was thinking of settling. He wound up in Africa in the early sixties almost by accident: at that time, Bernhard Grzimek was setting up the Serengeti Research Project in Tanzania and needed—Klingel says—someone who could speak English and drive on the "wrong" side of the road. The rest, as they say, is history. Klingel's current research interests include hippo communication and the migrations of Grevy's zebra, another species he has been observing for years. His home base is the University of Braunschweig, Germany, where he is a professor of zoology. For an introduction to hippos and many other mammals, Klingel recommends Richard Estes's *The Behavior Guide to Africa's Mammals* (Berkeley: University of California Press, 1990).

A contributing editor to *Natural History,* anthropologist **Samuel M. Wilson** (page 58) acquired his love for cricket in 1981, while helping Australian archeologist Richard Baker survey for sites in the wilds of Arnhem Land; as they went about their work, they listened to the Test Series between England and Australia on a shortwave radio (Australia won). In researching his article, Wilson used the Internet, the worldwide computer network, to obtain the results of cricket matches dating back to the last century. The Internet is one way that cricket fans keep in touch and share statistics, news items, and anecdotes. A good place to start, Wilson says, is with Cricinfo, a database housed at the Oregon Institute of Science and Technology, but organized and maintained by enthusiasts in England, India, the United States, and Australia (the E-mail address is cricinfo.cse.ogi.edu). Wilson is an associate professor of anthropology at the University of Texas at Austin. For additional reading he recommends *Island Cricketers,* by Clyde Walcott (London: Hodder and Stoughton, 1958), and *Beyond a Boundary,* by C. L. James (New York: Pantheon, 1984).

To get the best angle on his subject, **Konrad Wothe** (page 84) shimmies up a tree trunk in the Sumatran rain forest. Born in 1952 in Munich, he became interested in nature photography when he was eight years old. Soon he was building his own cameras. At first, he made a simple wooden device, but he later constructed mirror-reflex and 360-degree panoramic cameras, both of which won prizes in scientific competitions. A freelance wildlife photographer and filmmaker with a university degree in biology, Wothe has worked in India, Southeast Asia, East Africa, Madagascar, North America, Russia, and Antarctica. Several of his photographs have won first prizes in the BBC wildlife photograph competition. In order to photograph the orangutan in this month's "Natural Moment," he had to swim across a river with his camera held high above his head. Once in shallow water and in good position, Wothe clicked off an entire roll of film as the female orangutan hung upside down to drink from the river. He used a Canon EOS1 with a 80-200 zoom lens.



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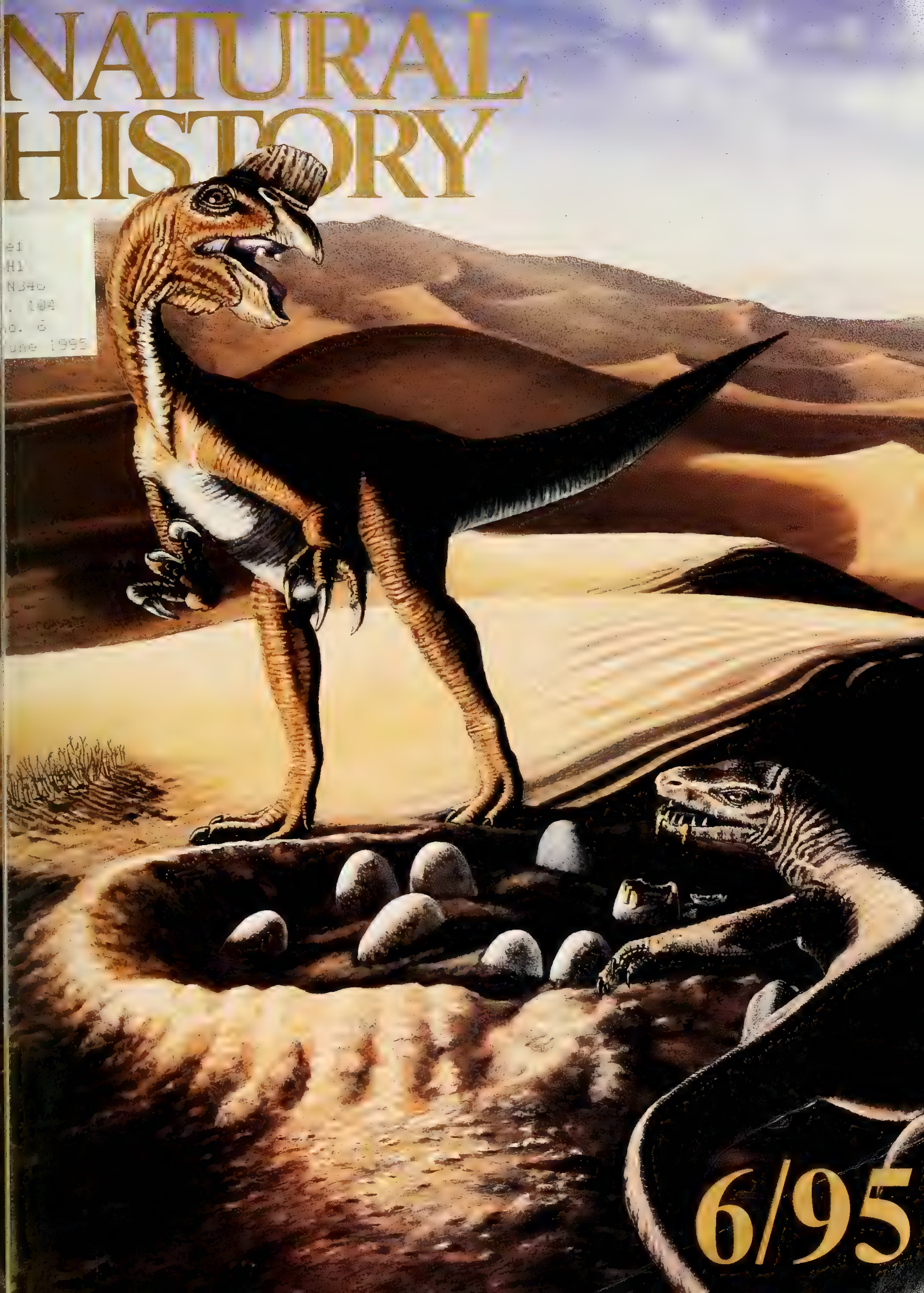

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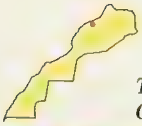
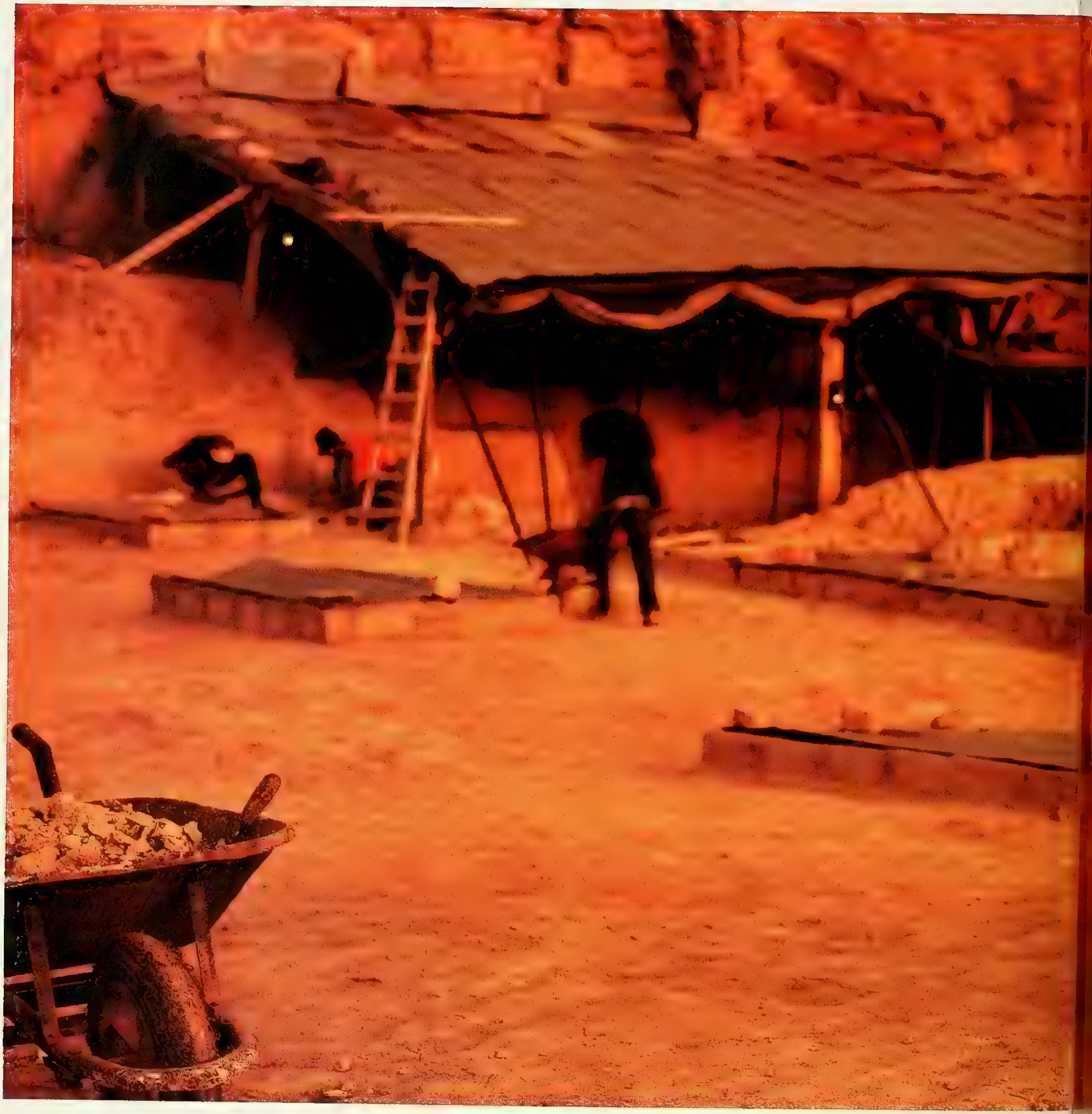


Thomas Quarry
Casablanca, Morocco



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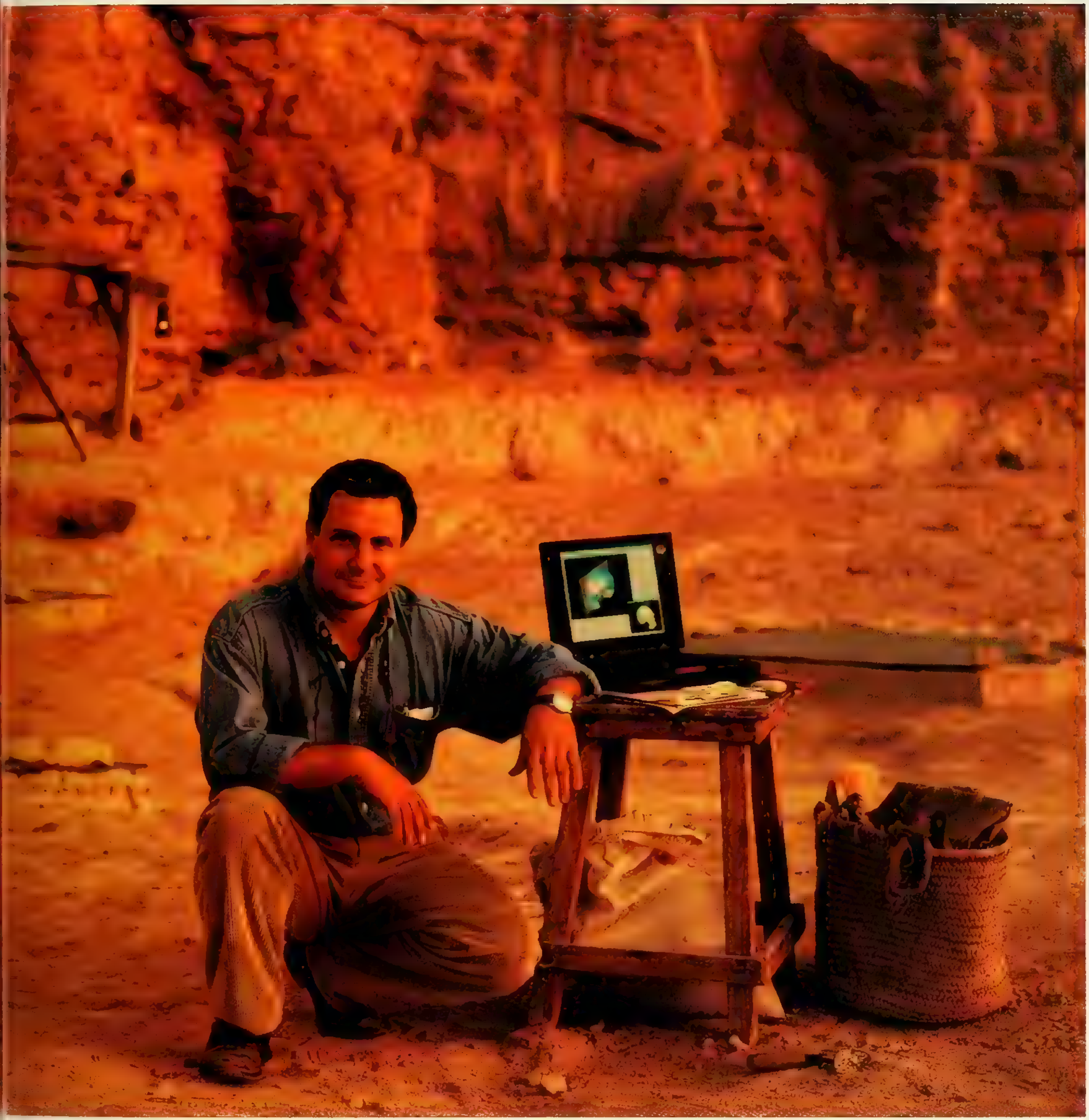

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COVER: An *Oviraptor* defends its eggs against a predatory lizard. Story on page 56. *Painting by Gary Staab.*

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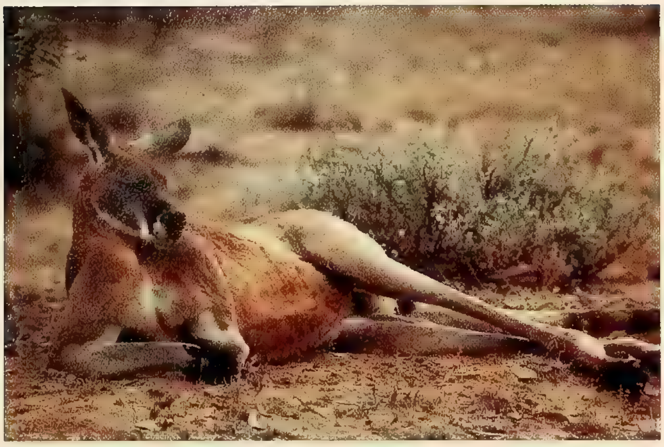
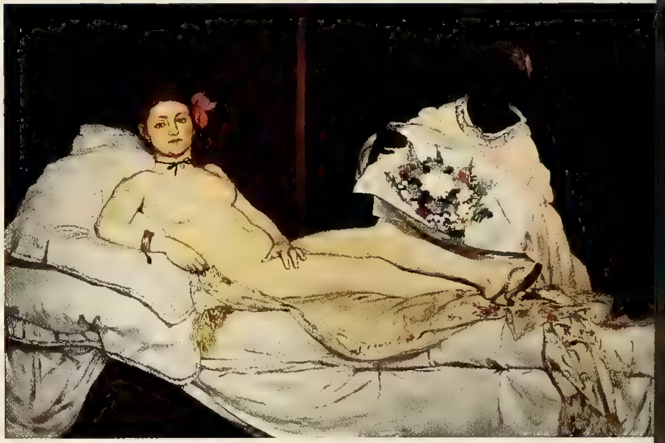


Erich Lessing; Art Resource, N



MARSUPIAL MANET

When I opened to the first page of "Red Kangaroos, the Kings of Cool" (April 1995), I laughed out loud. The pose of the elegant red kangaroo in the outback is strikingly similar to that of Manet's *Olympia.*

JACQUELINE ECKHOUS
Bingham Farms, Michigan

The Manet (above, right) hangs in the Musée d'Orsay in Paris. The reclining red kangaroo appears in *Mitsuaki Iwago's Kangaroos,* published by Chronicle Books, San Francisco.—*Ed.*

SNAKES, INSECTS—AND HUMANS?

Kurt Schwenk's description of his study of reptilian odor detection ("The Serpent's Tongue," April 1995) was especially interesting to me. For more than thirty years, entomologists have been studying how insects orient themselves along scent trails by means of paired chemoreceptors—in this case, antennae. Many insects use these organs to detect the varying concentrations of odors along trails that may lead to food or mates. Just as the author demonstrated the disorienting effect of removing tips of forked tongues in test snakes, earlier researchers found that the removal of a single antenna causes ants to veer to one side as they cross back and forth along a trail. Gluing antennae in a crossed position causes still greater confusion.

Orientation to pheromone trails is so important in many insects that entomologists have developed methods to disrupt this communication system with synthetic scents. By blocking behaviors that lead to activities such as mating, we can control certain pest species.

A final note: The author states that vomeronasal organs (VNO), sensory cells that serve as receptor sites for pheromone cues, are lacking in humans. However, researchers at the University of Utah have recently identified what they believe is the VNO at the base of the human nose.

JACK W. JENKINS
Litchfield Park, Arizona

KURT SCHWENK REPLIES: Insect chemosensory studies have long indicated the importance of paired antennae for locating and following pheromone trails. Some moths may also orient along airborne odor plumes, and recent work shows that lobsters similarly use their lateral antennules to follow waterborne plumes. (Interestingly, lobsters "flick" their antennules in a behavior that may be analogous to tongue flicking in snakes and lizards.) One important difference, however, is that in these invertebrates the antenna is the chemosensor, whereas in snakes the tongue is merely a sampling device and not, itself, the sensory organ. The insect studies should have provided early clues to the function of the forked tongue.

While it is true that some adult humans have a pit in the nasal septum containing a small patch of poorly characterized cells, in my judgment, the studies that purport to
demonstrate a functional human VNO ar
flawed, despite reports to the contrary. Th
most convincing studies have yielded ei
ther equivocal or negative results.

VULTURES' STRONG STOMACHS

David Houston, in his fascinating arti
cle "To the Vultures Belong the Spoils
(September 1994), points out that vulture
sometimes eat carrion that is several day
old. Since vultures seem to thrive on thi
diet, I have often wondered why they ar
not studied for their antibiotic digestiv
properties. What protects vultures fro
being poisoned by their apparently germ
laden, spoiled food?

DONALD A. WINDSO
Norwich, New Yo

DAVID HOUSTON REPLIES: Vultures do n
normally feed on food that is badly de
cayed. Like many scavenging animal
however, they will eat meat that is quit
bad if they are starving. The ability to to
erate partly decomposed food is n
unique to vultures, however. My own dog
have a particular ability to locate (an
snack upon) revoltingly old sheep ca
casses during a walk. Pigs will eat almo
anything. And we humans may have als
evolved from an ancestor that was a parti
scavenger. Our own digestive tract has re
markable abilities to deal with rottin
food, and many of our choicest delicacie
are actually based on products of micr
bial decomposition—think of all thos
rich cheeses and fine wines!

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Age-Old Fallacies of Thinking and Stinking

Over the centuries, myths about human subgroups have followed a persistent pattern of illogic

by Stephen Jay Gould

We shudder at the thought of repeating the initial sins of our species. Thus, Hamlet's uncle bewails his act of fratricide by recalling Cain's slaying of Abel:

O! my offense is rank, it smells to heaven;
It hath the primal eldest curse upon't;
A brother's murder!

Such metaphors of unsavory odor are especially powerful because our sense of smell lies so deep in our evolutionary construction, yet remains (perhaps for this reason) so undervalued and often unmentioned in our culture. A later seventeenth-century English writer recognized this potency and particularly warned his readers against using olfactory metaphors because common people will take them literally:

> Metaphorical expression did often proceed into a literal construction, but was a fraudulent illation. . . . How dangerous it is in sensible things to use metaphorical expressions unto the people, and what absurd conceits they will swallow in their literals.

This quotation comes from a chapter in the 1646 work of Sir Thomas Browne, *Pseudodoxia Epidemica: or, Enquiries Into Very Many Received Tenents [sic], and Commonly Presumed Truths.* Browne, a physician from Norwich, is better known for his wonderful and still widely read work of 1642, the part autobiographical, part philosophical, and part whimsical *Religio Medici,* or "Religion of a Doctor." The *Pseudodoxia Epidemica* (his Latinized title for a plethora of false truths) is the granddaddy of a most honorable genre still vigorously pursued—exposés of common errors and popular ignorance, particularly the false beliefs most likely to cause social harm.

I cited Browne's statement from the one chapter (among more than a hundred) sure to send shudders down the spine of modern readers—his debunking of the common belief "That Jews Stink." Browne, although almost maximally philosemitic by the standards of his century, was not free of all prejudicial feelings against Jews. He attributed the origin of the canard about Jewish malodor—hence, my earlier quotation—to a falsely literal reading of a metaphor legitimately applied (or so he thought) to the descendants of people who had advocated the crucifixion of Jesus. Browne wrote: "Now the ground that begat or propagated this assertion, might be the distasteful averseness of the Christian from the Jew, upon the villainy of that fact, which made them abominable and stink in the nostrils of all men." (Modern apostles of political correctness should ponder the noninclusiveness of Browne's "all men" in this context.)

As a rationale for debunking a compendium of common errors, Browne correctly notes that false beliefs arise from incorrect theories about nature and therefore serve as active impediments to knowledge, not just as laughable signs of primitivity. "To purchase a clear and warrantable body of truth, we must forget and part with much we know." Moreover, Browne notes, truth is hard to ascertain, and ignorance is far more common than accuracy. Writing in the mid-seventeenth century, Browne uses "America" as a metaphor for domains of uncharted ignorance, and he bewails our failure to use good tools of reason as guides through this terra incognita: "We find no open tract . . . in this labyrinth; but are oft-times fain to wander in the America and untravelled parts of truth."

The *Pseudodoxia Epidemica,* Browne's peregrination through the maze of human ignorance, contains 113 chapters gathered into seven books on such general topics as mineral and vegetable bodies, animals, humans, Bible tales, and geographical and historical myths. Browne debunks quite an array of common opinions, including claims that elephants have no joints, that the legs of badgers are shorter on one side than the other, and that ostriches can digest iron.

As an example of his style of argument, consider book 3, chapter 4: "That a bever [*sic*] to escape the hunter, bites off his testicles or stones"—a harsh tactic that, according to legend, either distracts the pursuer or persuades him to settle for a smaller meal than an entire body. Browne labels this belief as "a tenet very ancient; and hath had thereby advantages of propagation. . . . The Egyptians also failed in the ground of their hieroglyphick, when they expressed the punishment of adultery by the bever depriving himself of his testicles, which was amongst them the penalty of such incontinency."

Browne prided himself on using a mixture of reason and observation to achieve his debunking. He begins by trying to identify the source of error—in this case a false etymological inference from the

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beaver's Latin name, *Castor,* which does not share the same root with "castration" (as the legend had assumed) but derives ultimately from a Sanskrit word for "musk"; and an incorrect interpretation of purposeful mutilation from the internal position, and therefore near invisibility, of the beaver's testicles. He then cites the factual evidence of intact males and the reasoned argument that a beaver couldn't even reach his own testicles if he wanted to bite them off (and thus, cleverly, the source of common error—the external invisibility of the testicles—becomes the proof of falsity!).

> The testicles properly so called, are of a lesser magnitude, and seated inwardly upon the loins: and therefore it were not only a fruitless attempt, but impossible act, to eunuchate or castrate themselves: and might be an hazardous practice of art, if at all attempted by others.

Book 7, chapter 2 debunks the legend "that a man hath one rib less than a woman"—"a common conceit derived from the history of Genesis, wherein it stands delivered, that Eve was framed out of a rib of Adam." (I regret to report that this bit of nonsense still commands some support. I recently appeared on a nationally televised call-in show for high school students, and one young woman, a creationist, cited this "well-known fact" as proof of the Bible's inerrancy and evolution's falsity.) Again, Browne opts for his mixture of logic and observation in stating that "this will not consist with reason or inspection." A simple count on skeletons (Browne was a physician by trade) affirms equality of number between sexes. Moreover, reason provides no argument for assuming that Adam's single loss would be propagated to future members of his sex:

> Although we concede there wanted one rib in the sceleton of Adam, yet were it repugnant unto reason and common observation, that his posterity should want the same [in the old meaning of "want" as "lack"]. For we observe that mutilations are not transmitted from father unto son; the blind begetting such as can see, men with one eye children with two, and cripples mutilate in their own persons do come out perfect in their generations.

Book 4, chapter 10—"That Jews Stink"—is one of the longest, and clearly held special importance for Dr. Browne. His arguments are more elaborate, but he follows the same procedure used to dispel less noxious myths—citation of contravening facts interlaced with more general support from logic and reason.

Joseph Farris

Browne begins with a statement of the fallacy: "That Jews stink naturally, that is, that in their race and nation there is an evil savor, is a received opinion." Browne then allows that species may have distinctive odors, and that individual men surely do:

> Aristotle says no animal smells sweet save the pard. We confess that beside the smell of the species, there may be individual odors, and every man may have a proper and peculiar savor, which although not perceptible unto man, who hath this sense but weak, is yet sensible unto dogs, who hereby can single out their masters in the dark.

In principle, then, discrete groups of humans might carry distinctive odors, but reason and observation permit no such attribution to Jews as a group: "That an unsavory odor is gentilitous or national unto the Jews, if rightly understood, we cannot well concede, nor will the information of Reason or Sense induce it."

On factual grounds, direct sniffing has provided no evidence for this noxious legend:

> This offensive odor is no way discoverable in their Synagogues where many are, and by reason of their number could not be concealed: nor is the same discernible in commerce or conversation with such as are cleanly in apparel, and decent in their houses.

The "test case" of Jewish converts to Christianity proves the point, for even the worst bigots do not accuse such people of smelling bad: "Unto converted Jews who are of the same seed, no man inputeth this unsavory odor; as though aromatized by their conversion, they lost their scent with their religion, and smelt no longer." Indeed, if people of Jewish lineage could be identified by smell, the Inquisition would greatly benefit from a surefire guide for identifying insincere converts:

> There are at present many thousand Jews in Spain . . . and some dispensed withal even to the degree of Priesthood; it is a matter very considerable, and could they be smelled out, would much advantage, not only the Church of Christ, but also the Coffers of Princes.

Turning to arguments from reason, foul odors might arise among groups of people from unhealthy habits of diet or hygiene. But Jewish dietary laws guarantee moderation and good sense, while drinking habits tend to abstemiousness—"seldom offending in ebriety or excess of drink, nor erring in gulosity or superfluity of meats; whereby they prevent indigestion and crudities, and consequently putrescence of humors."

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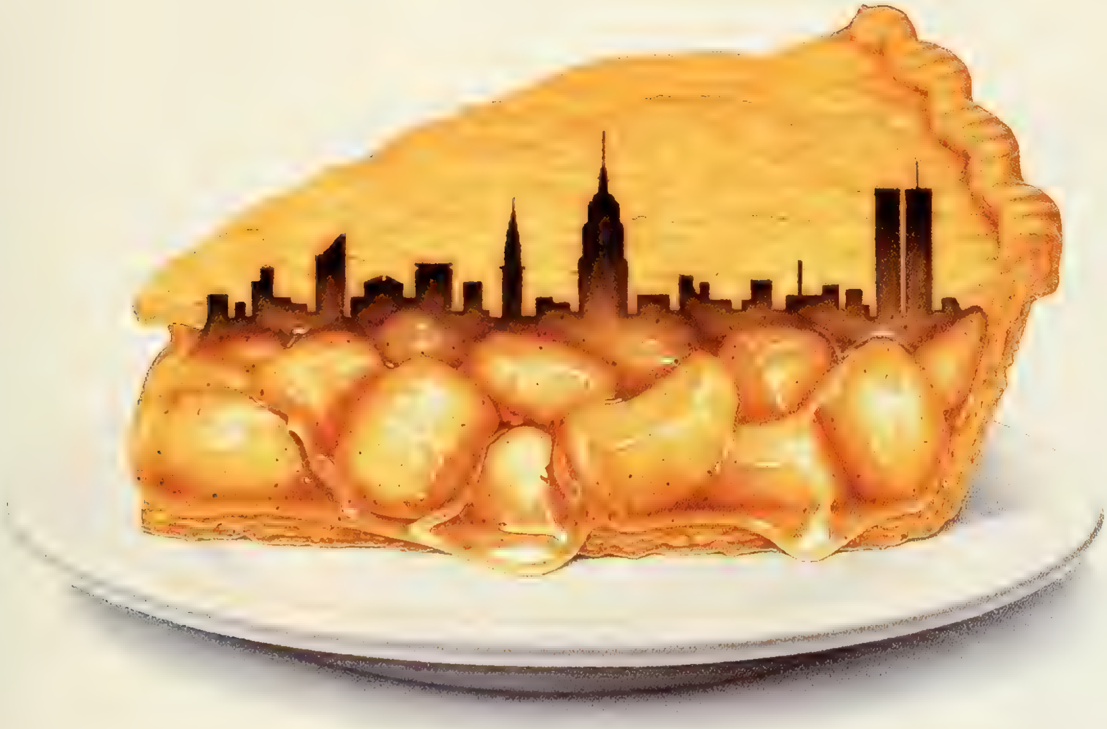

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If no reason can therefore be found in Jewish habits of life, the only conceivable rationale for a noxious racial odor would lie in a divine "curse derived upon them by Christ . . . as a badge or brand of generation that crucified their Salvator." But Browne rejects this proposal even more forcefully as a "conceit without all warrant; and an easie way to take off dispute in what point of obscurity soever." For invocation of miraculous agency, when no natural explanation can be found, is a coward's or lazy man's escape from failure. (Browne does not object to heavenly intervention for truly great events like Noah's flood or the parting of the Red Sea, but a reliance upon miracles for small items, like the putative racial odor of unfairly stigmatized people, makes a mockery of divine grandeur. Browne then heaps similar ridicule on the legend that Ireland has no snakes because Saint Patrick cast them out with his rod. Such inappropriate claims for a myriad of minor miracles only stifles discussion of the nature of phenomena and the workings of genuine causes.)

But Browne then caps his case against the proposition "that Jews stink" with an even stronger argument based on reason. The entire subject, he argues, makes no sense because the category in question—the Jewish people—does not represent the kind of entity that could bear such properties as a distinctive national odor.

Among the major fallacies of human reason, such "category mistakes" are especially common in the identification of groups and the definition of their characters—problems of special concern to taxonomists like myself. Much of Browne's text is archaic, and strangely fascinating therefore as a kind of conceptual fossil. But his struggle with errors of categories in debunking the proposition "that Jews stink" interleaves a layer of modern relevance and uncovers a different kind of reason for contemporary interest in the arguments of *Pseudodoxia Epidemica*.

Browne begins by noting that traits of individuals can't automatically be extended to properties of groups. We do not doubt that individuals have distinctive odors, but groups might span the full range of individual differences, and thereby fail to maintain any special identity. What kind of group might therefore qualify as a good candidate for such distinctive properties?

JOSEPH FARRIS

"Do you suppose it could be the greenhouse effect?"

Browne argues that such a group would have to be tightly defined, either by strict criteria of genealogy (so that members might share properties by heredity of unique descent) or of common habits and modes of life not followed by other people (but Browne had already shown that Jewish lifestyles of moderation and hygiene disprove any claim for unsavory national odor).

Browne then clinches his case by arguing that the Jewish people do not represent a strict genealogical group. Jews have been dispersed throughout the world, reviled and despised, expelled and excluded. Many subgroups have been lost by assimilation; others diluted by extensive intermarriage. Most nations, in fact, are strongly commingled and therefore do not represent discrete groups by genealogical definition; this common tendency has been exaggerated among the Jewish people. Jews are not a distinct hereditary group, and therefore cannot have such properties as a national odor:

> There will be found no easie assurance to fasten a material or temperamental propriety upon any nation; there being scarce any condition . . . which is not exhausted or obscured from the commixture of introvenient nationals either by commerce or conquest; much more will it be difficult to make out this affection in the Jews; whose race however pretended to be pure, must needs have suffered inseparable commixtures with nations of all sorts. . . . It being therefore acknowledged that some [Jews] are lost, evident that others are mixed, and not assured that any are distinct, it will be hard to establish this quality [of national odor] upon the Jews.

In many years of pondering over fallacious theories of biological determinism and noting their extraordinary persistence and tendency to reemerge after presumed extirpation (like heads of the Lernaean Hydra, or clumps of crab grass on a suburban lawn, to cite the standard metaphors of well-separated centuries and social concerns), I have been struck by a property that I call "surrogacy." Specific arguments raise a definite charge against a particular group—that Jews stink, that Irishmen drink, that women love mink, that Africans can't think—but each specific claim acts as a surrogate for any other. The general form of argument is always the same and always permeated by identical fallacies over the centuries. Scratch the argument that women, by their biological nature, cannot be effective as heads of state and you will uncover the same structure of bad influence underlying someone else's claim that African Americans will never form a high percentage of the pool of Ph.D. candidates.

Thus, Browne's old refutation of the myth "that Jews stink" continues to be relevant for our modern struggle, because the form of his argument applies to our current devaluings of people for supposedly inborn and unalterable defects of intelligence or moral vision. Fortunately (since I belong to the group), Jews are not taking much heat these days (although I need hardly mention the searing events of my parents' generation to remind everyone that current acceptance should breed no complacency). This season's favorite myth has recalled another venerable chapter in this general form of infamy—*The Bell Curve*'s version of the claim that people of African descent have, on average, less innate intelligence than all other folks.

Following Browne's strategy, this claim can be debunked with a mixture of factual citation and logical argument. I shall not go through the full exercise here, lest this essay become a book (see my review of *The Bell Curve* in *The New Yorker*, November 1994). But I do wish to emphasize that Browne's crowning point in refuting the legend "that Jews stink"—his explication of category mistakes in defining Jews as a biological group—also undermines the modern myth of black intellectual inferiority, from Jensen and Shockley in the 1960s to Murray and Herrnstein today.

The African American population of the United States today does not form a genealogical unit in the same sense that Browne's Jews lacked inclusive definition by descent. As a legacy of our ugly history of racism, anyone with a visually evident component of African ancestry belongs to the category of "black," even though many persons so designated have substantial, often majoritarian, Caucasian ancestry as well. (An old "trick" question for baseball aficionados asks: "What Italian American player hit more than forty home runs for the Brooklyn Dodgers in 1953?" The answer is Roy Campanella, who had a Caucasian Italian father and a black mother, but who, by our social conventions, is always identified as black.)

(As a footnote on the theme of surrogacy, explanations of the identical category mistake for blacks and Jews have often taken the same prejudicial form of blaming the victim. Browne, although generally and refreshingly free of anti-Jewish bias, cites a particularly ugly argument in explaining high rates of intermixing between Jews and Christians—the supposed lasciviousness of Jewish women and their preference for blond Christian men over swarthy and unattractive Jews. Browne writes: "Nor are fornications infrequent between them both [Jewish women and Christian men]; there commonly passing opinions of invitement, that their women desire copulation with them rather than their own nation, and affect Christian carnality above circumcised venery." American racists often made the same claim during slavery days—a particularly disgraceful lie in this case, for the argument works to excuse rapists by blaming the truly powerless. For example, Louis Agassiz wrote in 1863: "As soon as the sexual desires are awakening in the young men of the South, they find it easy to gratify themselves by the readiness with which they are met by colored [halfbreed] house servants. . . . This blunts his better instincts in that direction and leads him gradually to seek more spicy partners, as I have heard the full blacks called by fast young men.")

Obviously, we cannot make a coherent claim for "blacks" being innately anything by heredity if the people so categorized do not form a distinctive genealogical grouping. But the category mistake goes far, far deeper than dilution by extensive intermixture with other populations. The most

HistoriQue.

"From the chateau's topmost turret to the quayside cafés, time stands still here, lingering behind stone walls and along lazy lanes."

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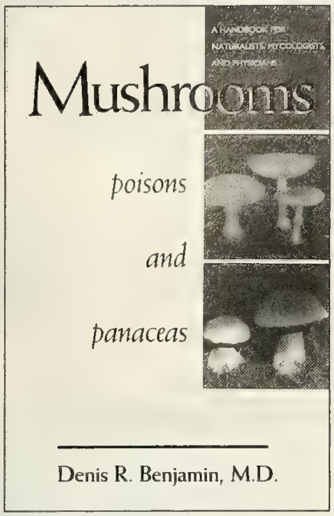

A HANDBOOK FOR NATURALISTS, MYCOLOGISTS, AND PHYSICIANS

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poisons

and

panaceas

Denis R. Benjamin, M.D.

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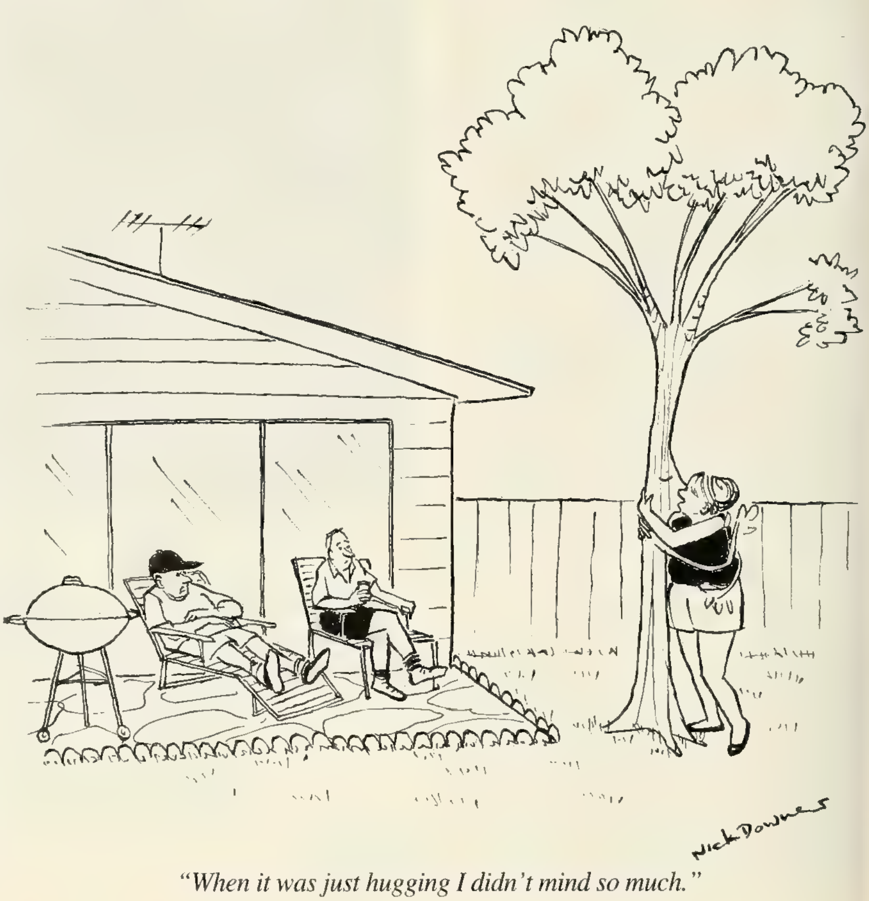
W.H. FREEMAN

exciting, and still emerging, discovery in modern paleoanthropology and human genetics will force us to rethink the entire question of human categories in a radical way. We shall be compelled to recognize that "African black" cannot rank as a racial group with such conventional populations as "Native American," "European Caucasian," or "East Asian," but must be viewed as something more inclusive than all the others combined, not really definable as a discrete group, and therefore not available for such canards as "African blacks are less intelligent" or "African blacks sure can play basketball."

As I have written in several essays of this series, the past decade of anthropology has featured a lively debate about the origin of the only living human species, *Homo sapiens.* Did our species emerge separately on three continents (Africa, Europe, and Asia) from precursor populations of *Homo erectus* inhabiting all these areas—the so-called multiregionalist view? Or did *Homo sapiens* arise in one place, probably Africa, from just one of these *Homo erectus* populations and then spread out later to cover the globe—the so-called out-of-Africa view?

The tides of argument have swung back and forth, but recent evidence seems to be cascading toward Out of Africa. As more and more genes are sequenced and analyzed for their variation among human racial groups, and as we reconstruct genealogical trees based upon these genetic differences, the same strong signal and pattern seems to be emerging (see *Science,* March 3, 1995, pp. 1272–73, for a report on several studies presented at this year's annual meeting of the American Association for the Advancement of Science). *Homo sapiens* emerged in Africa; the migration into the rest of the world did not begin until 112,000 to 280,000 years ago, with the latest, more technologically sophisticated studies favoring dates near the younger end of this spectrum.

In other words, *all* non-African racial diversity—whites, yellows, reds, everyone from the Hopi to the Norwegians to the Fijians—may not be much older than 100,000 years. By contrast, *Homo sapiens* has lived in Africa for a longer time. Consequently, since genetic diversity roughly correlates with time available for evolutionary change, genetic variety among Africans alone exceeds the sum total of genetic diversity for everyone else in the rest of the world combined! How, therefore, can we lump "African blacks" together as a single group, and imbue them with traits either favorable or unfavorable, when they represent more evolutionary



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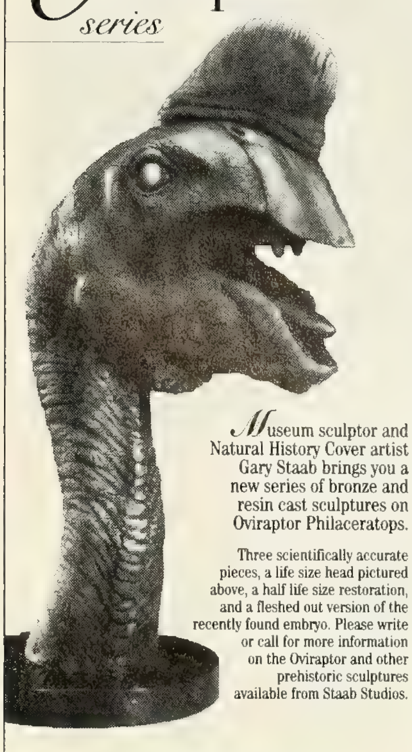

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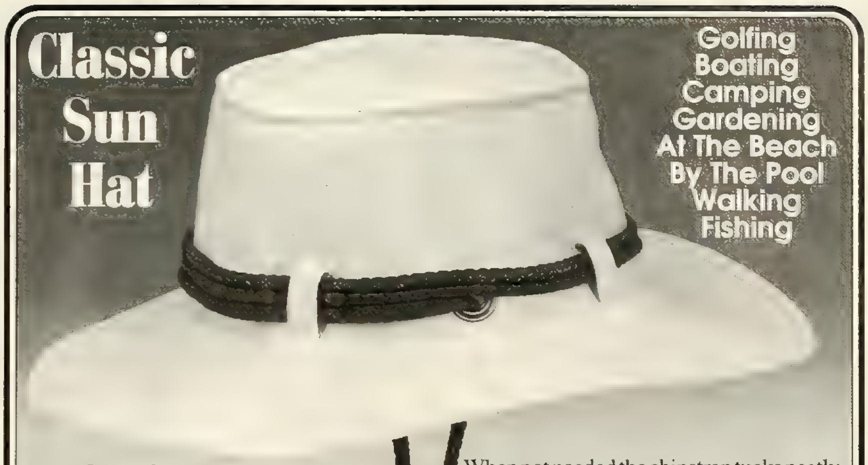
space and more genetic variety than we find in all non-African people in all the rest of the world? Africa is most of humanity by any proper genealogical definition; all the rest of us occupy a branch within the African tree. This non-African branch has surely flourished but can never be topologically more than a subsection within an African structure.

We will need many years, and much pondering, to assimilate the theoretical, conceptual, and iconographic implications of this startling reorientation in our views about the nature and meaning of human diversity. For starters, though, I suggest that we finally abandon such senseless statements as "African blacks have more rhythm, less intelligence, greater athleticism." Such claims, besides their social perniciousness, have no meaning if Africans cannot be construed as a coherent group because they represent more diversity than all the rest of the world put together.

Our greatest intellectual adventures often occur within us—not in the restless search for new facts and new objects on the earth or in the stars, but from a need to expunge old prejudices and build new conceptual structures. No hunt can have a sweeter reward, a more admirable goal, than the excitement of thoroughly revised understanding—the inward journey that thrills real scholars and scares the bejesus out of the rest of us. We need to make such an internal expedition in reconceptualizing our views of human genealogy and the meaning of evolutionary diversity. Thomas Browne—for we must award him the last word—praised such inward adventures above all other intellectual excitement. Interestingly, in the same passage, he also invoked Africa as a metaphor for unknown wonder. He could not have known the uncanny literal accuracy of his words (from *Religio Medici*, book 1, section 15):

> I could never content my contemplation with those general pieces of wonder, the flux and reflux of the sea, the increase of Nile, the conversion of the [compass] needle to the north; and have studied to match and parallel those in the more obvious and neglected pieces of nature, which without further travel I can do in the cosmography of myself; we carry with us the wonders we seek without us: there is all Africa and her prodigies in us; we are that bold and adventurous piece of nature.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.



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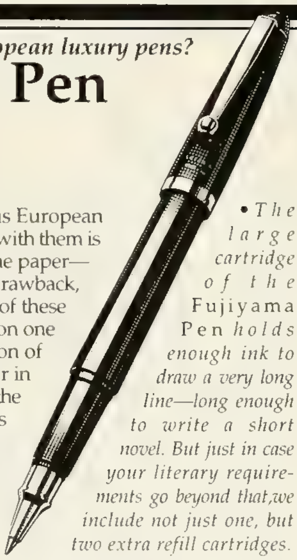

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It all began in 1965 . . .

by Roger L. Welsch

At my age, birthdays are not welcome events, so when I turned forty, I changed the accounting system (much as Congress does) and began observing Roger Welsch Recognition Day. A couple of months ago, for the Eighteenth Annual Roger Welsch Recognition Day (see? doesn't that sound better?), my wife, Lovely Linda, veered from her usual habit of giving me presents that are utterly mysterious. (Why a book on insomnia, for example, when I sleep like a hibernating bear? Why a road atlas of the United States when I never drive anywhere? Why a selection of men's colognes when—well, never mind.)

This year Linda gave me a home-size version of arguably the most dramatic scientific advance of this century (perhaps the greatest discovery of the century if no one comes up with cold fusion in the next five years), a technological wonder whose benefits for humankind have only begun to be explored. By now you've guessed it: Linda gave me a Lava Lite.

To begin with, let's look at the nomenclature. Some people call them Lava Lites; some, Lava Lamps. Technically and officially, they are Lava Lite Lamps. I like to call mine a Lava Lamp because whoever I'm talking with then tries to use the phrase and quickly finds there's more to a Lava Lamp than meets the tongue. The tendency is to call it a "lava lomp" or a "laahva lamp," neither of which sits well in the American mouth (except perhaps the second, in New England).

In fact, owning a Lava Lite is altogether a far more complicated matter than one might suspect, even for the phonically agile. For one thing, there is the terrible noise. "Ooooooh! Aaaaaaah! Gloop gloop gloop gloop GLOP!" These are not sounds the lamp makes but a very limited sample of the inventory of noises Linda, Antonia, and I generate as we watch this natural wonder. Other frequently encountered comments aimed at our lamp these days are "Whoooooooa!" "Eeeeeeeek!" and "Buuuuu-LOOOTCH!"

Perhaps the most weighty burden the gift of a Lava Lite Lamp carries with it is the unexpected obligation of the Lava Philosophy, printed right there on the side of the box the lamp comes in and shown prominently on the instruction manual and warranty sheet:

> Lava is a Philosophy. The primordial ooze that once ruled our world has been captured in Perpetual Motion. Lava is the Moment. Its ever changing patterns are hypnotizing yet invigorating. Lava is an art form, a classic and at the same time . . . progressive. Lava is pre-historic and post-modern. Lava is here to stay.

I was unsure exactly how to make it clear to my lamp that I was fully prepared to commit myself to the Lava Philosophy—with witnesses? before a notary public? formally dressed? buck naked? I decided maybe I should check with Lava-Simplex Internationale, the Chicago-based techno-philosophy corporation that distributes Lava Lites. Lava spokeswoman Pamela McDonald assured me that in keeping with its obvious Zen origins, the Way of the Lava is an individual and personal commitment.

Comforted, I thought that while I had McDonald on the phone, I would take care of some other questions I had about the glowing natural wonder bubbling in my living room (the Lava Lite, that is, not my black Labrador, Lucky). How long ago was the Lava Lite invented? I thought I remembered gaping slack jawed and glassy eyed at Lava Lites in the window of the Cornhusker Hotel Novelty Shop in Lincoln, Nebraska, when I was just a little kid, but McDonald told me the Lava Lite was invented in 1965 by an English engineer by the name of Craven Walker. (Yes, I know, the only possible conclusion is that I was gaping slack jawed and glassy eyed at Lava Lites in the window of the Cornhusker Hotel Novelty Shop when I was thirty years old.)

When asked if she happened to know the oldest lamp still lavaing, McDonald said that some of the originals are still perking away, some ten thousand eruptions later. She wouldn't tell me precisely how many Lava Lites have been sold in the past thirty years or how many are sold in a year—further mysteries of the Lava Philosophy, I guess—but she hinted that total sales are in the "millions." She confirmed my impression that the Lava Lite was big in the sixties and seventies, faded away in the eighties, and has experienced a recent resurgence of popularity.

"I'll bet that's because aging hippies like me finally have the money to buy them, right?" I guessed.

"No," she countered. "We think it's because young people remember seeing Lava Lites at their parents' and grandparents' homes and now want one for themselves. It's a nostalgia thing." Ouch. I'm still wishing for new things others consider antiques. So much for a happy Eighteenth Annual Recognition Day.

The Lava Philosophy, it turns out, is a relatively new part of Lava Lite ownership. McDonald reports that inclusion of the Philosophy started only five years ago and sprang from an unescapable reality. Lava Lite owners were writing in by the thousands, expressing gratitude for the soothing, therapeutic properties of their Lites, Philosophy or not, and so someone at the office just put down on the box what seemed to be pretty much the case anyway. And that sure makes sense to me. ("Whoooosh! Glooooop!")

Perhaps the most interesting line of our conversation came serendipitously when I asked McDonald the ages of those writing the bulk of Lava Lite fan mail. "Across the board, young and old," she said. Then she added, "Right now it's mostly earthquake letters."

"Earthquake letters?"

"Yes, people in California are concerned about getting replacements for Lava Lites broken in the recent quakes."

That response touched directly on a concern that had bothered Linda, Antonia, and me for weeks. (Winters are long and slow in Nebraska.) Linda tells me that when she was considering a Lava Lite as a Recognition Day gift, she also looked at Tornado Lamps (not made by Lava-Simplex Internationale, I should note). She decided that, since we spend a good number of hours each year cringing in our storm cellar dreading the sound of a tornado removing the house from over us, tornado-in-a-lamp might not be much fun for us. Lava, on the other hand, is one of the few natural disasters Nebraska has been spared for a couple of millennia. So, she got me a Lava Lite Lamp.

Do Hawaiians, I wondered, remain uncharmed by lava-in-a-bottle? Perhaps they are the ones who take delight in the Tornado Lamps and the Cyclone Philosophy. I have seen little desktop lamps that provide the "soothing motion" of a miniature tsunami constantly sweeping back and forth. Who buys these? How do coastal Japanese feel about the mesmerizing effects of a tidal wave?

Thus, as with any solid scientific research, my work with Lava Lites has only opened more questions. How did natural disaster lamps originate? Are they an outgrowth of the low-tech (but ever-popular) snow globe? What will the next trendy item be? Will it be a Richter 8.2 Lite? How about an Ozone Layer Depletion Lamp? Global Warming Lite? Fire Ant Farm Lamp? Overpopulation Nite Lite?

When asked about such research and marketing directions, Pamela McDonald said only, "No comment."

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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High Creek Fen, Colorado

by Robert H. Mohlenbrock

A grassy valley bounded on the east and west by mountain ranges of granite and limestone, South Park lies in central Colorado about twenty miles south of the resort community of Breckenridge. For the Ute Indians and their predecessors, the huge valley was a source of wild game and edible plants. European-American settlers, led by such explorers as Zebulon Pike, John C. Frémont, and Kit Carson, were attracted to the area in the early 1800s by the opportunity to trap beaver for the fur trade. In the 1860s, Sam Hartsell established a 200,000-acre ranch there, turning much of the land into pasture for livestock. Where the cattle haven't grazed, or haven't grazed recently, the vegetation is typical of dry plains.

Near the middle of South Park, as one approaches the historic village of Fairplay from the south along U. S. Highway 285, a small stand of blue spruces may be seen to the east of the road, about three-quarters of a mile away. Although blue spruce is otherwise uncommon in this valley setting, biologists apparently paid little attention to this stand until 1988, when David Cooper, a botanist at Colorado State University, ventured out to the trees and discovered a sedge-covered fen, created by the constant flow of groundwater to the surface. Just how exceptional the site was became apparent after Cooper revisited the site later that summer with William Weber, curator of the University of Colorado herbarium, and found more rare plant species there than in any other wetland site in Colorado.

Located on private property, some of the wetland's peat had been removed in the past, and more was scheduled to be mined. The Nature Conservancy therefore mounted a drive to acquire the land for preservation. Assisted by a group of fifth- and sixth-graders from Deer Creek Elementary School in nearby Bailey, who contributed to the effort by collecting one million pennies, the Nature Conservancy secured the 500-acre wetland and some of the surrounding land. Now called High Creek Fen, the site has been designated a Colorado Natural Area.

My wife and I visited High Creek Fen in mid-July to see it for ourselves. A gravel road leading to a small parking area brought us to within 300 feet of the wetland. On the remaining short hike, we saw diverse plants indigenous to the dry plains. Showy flowers of blue beardtongue, Indian paintbrush, and lousewort contrasted with the gray leaves and obscure flowers of fringed sage. Other common plants included daisy fleabane, false dandelion, and American hawkweed. We even saw small cactuses, some of them growin within a few feet of the wetland. As w walked, the flat, even terrain of the dr plains abruptly gave way to spongy, bogg ground built up from layers of peat. Hun mocks of living sedge arose within a ne work of rivulets and pools that coalesced t form High Creek.

A male short-fruited willow sheds its pollen. Opposite page: Shooting star blooms amid the bulrushes and blue spruce trees of High Creek Fen.

Harold E. Malde

A predictable selection of grasse sedges, and rushes grow in the fen, such a marsh bluegrass, reed grass, golden sedg woolly sedge, and long-styled rush. Colo ful, common wetland wildflowers ar monkshood, blue iris, shooting star, silve cinquefoil, creeping buttercup, hemloc parsley, bistort, and grass-of-parnassus.

One of the wetland's rarities is a dwa bulrush. Unlike most other bulrushes coarse sedges that can grow two to twel feet tall—this one is a slender plant abo four inches tall. A perennial, it spreads b means of rhizomes, as well as reproducin sexually by means of its tiny, flowerin spikelet and minute black seeds. The sp cies grows only in Alaska, parts of Canad the Yellowstone area, one locality in nort ern California, and at High Creek Fen.

A delicate beauty at High Creek Fen the Greenland primrose, a four-inch-ta plant with five white to violet petals. Ou side of the fen, it grows only in the Yello stone area, Alaska, the Yukon, British C lumbia, Greenland, and Labrador. Anoth delicate species is pale blue-eyed gras whose blooms have six petals that range color from white to very pale blue. The fla tened base of the stems and leaves identifi it as a member of the iris family. This sp cies is found at only a very few locations, of them in Colorado.

Relatively few woody plants grow in t fen. The blue spruces, which are on sligh elevated terrain at the center of the wetla (but in extremely wet surroundings nor theless), are the only ones that actually

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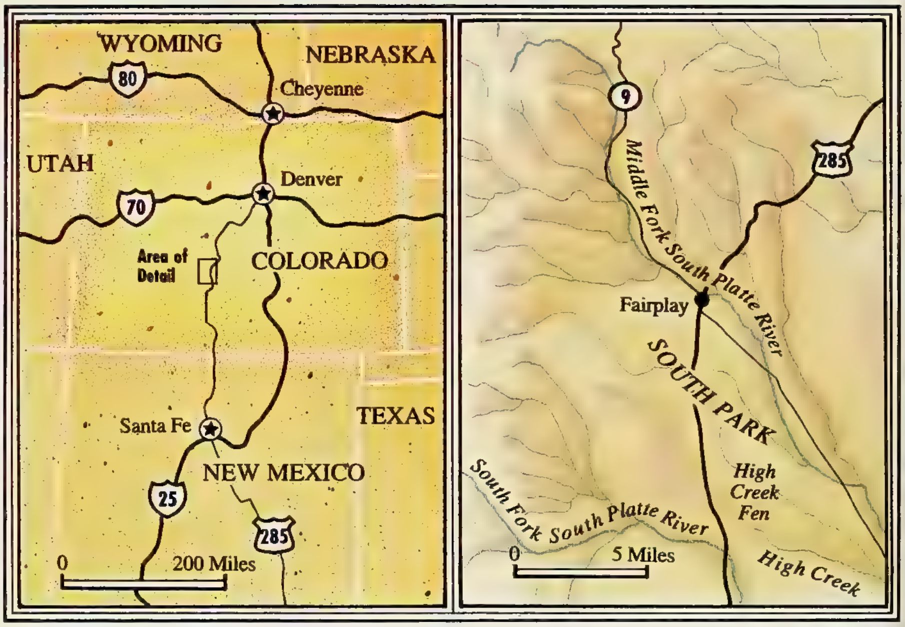
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The hoary willows at High Creek Fen are 450 miles away from any other population of the species.
Harold E. Malde

tain tree size, some being about twenty feet tall. Bog birch and western river birch are found here and there: the first is a dwarf species by nature; the second is apparently stunted by the oxygen-poor soil. Seven different species of willows can be identified, from the common flat-leaved willow and barren-ground willow to others that are unexpected for this part of the country, notably the myrtle-leaved willow and the hoary willow, whose leaves are backed by a dense, woolly white coat. These last two species represent isolated populations of arctic and northern Rocky Mountain plants that remained after the last ice age ended, ten or twelve thousand years ago. The nearest populations of these species lie 450 miles away.

One other shrub at High Creek Fen is the shrubby cinquefoil, common to many wetlands in the northern United States and adjacent Canada. Its yellow, inch-wide flowers are so attractive that this species is now a popular plant available in nurseries.

The fen's scattered pools of clear, standing water contain true aquatic plants. Among these are two kinds of bladderworts, whose intricate underwater branches bear dozens of tiny bladders that can be triggered to suck in and digest microscopic animal life. Other aquatic plants are the much-branched (but not carnivorous) hornwort, at least two kinds of pondweeds, and an aquatic sedge. Wilson's phalarope, a sandpiperlike bird, may be seen flying around in circles over the fen and then swooping down to stir up the rich bottom of a pool for invertebrates.

Our summertime visit to the fen was marred only by the deerflies, which began to take an interest in us as soon as we stepped into the wetland. At first only a few of these biting flies accosted us, but as we went deeper into the fen, more flies attacked us. Soon the swarm became unbearable, and we decided to retreat, running as best we could over the hummocky ground. I reasoned, or at least hoped, that as soon as we crossed into the dry plains, the deerflies would leave us alone—but no, they pursued us all the way to, and even into, our car. As I drove down the gravel road toward U. S. 285, the deerflies kept pace outside our windows and only gave up after I was able to "open up" on the paved highway.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the U. S. national forests and other parklands.

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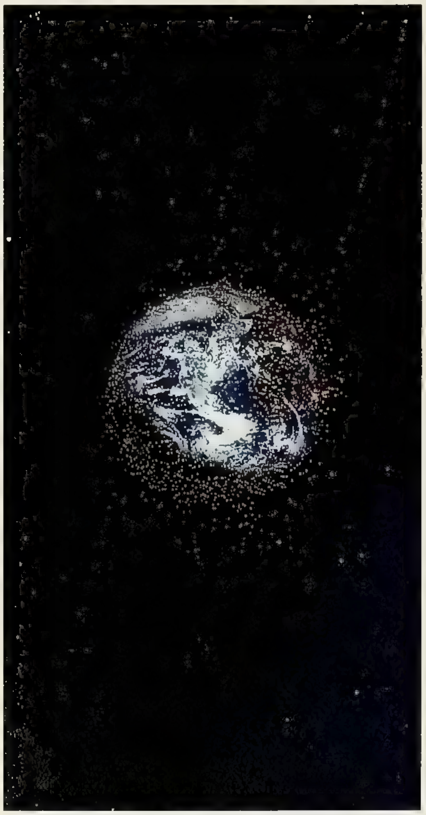
EXPLORER'S GUIDE
MANITOBA

by Joe Rao

Ever since the Soviet Union launched *Sputnik 1* on October 4, 1957, near-Earth space has gradually become more congested. Today, the merry-go-round of orbital traffic is populated by more than 7,000 objects big enough to track, ranging from the size and mass of a double-decker bus down to a softball. Most of the objects are small satellites or pieces of space debris, too faint to be spotted without a telescope. Nearly 300 satellites, however, are large enough and low enough to be seen with the naked eye if viewing conditions are good. Visible satellites usually measure at least twenty feet long and have orbits that bring them within 400 miles of Earth's surface. Many are as bright as the North Star, and a few, like the space shuttle and the Russian space station, *Mir,* are sometimes brighter than Sirius, the brightest star.

If you go outside and lie in a reclining lawn chair from about forty-five minutes to two hours after sunset, as the sky becomes reasonably dark, you should not have to wait more than ten or fifteen minutes before you catch sight of a satellite. The satellites are visible because they are high enough to reflect sunlight as they move across the darkening sky. Low satellites enter Earth's shadow about two hours after sunset and immediately vanish from view as they pursue an unseen path until they emerge from eclipse again.

British space researcher Desmond King-Hele noted that a satellite looks like "a star that has taken leave of its senses and decided to move off to another part of the sky." You may have seen a satellite without knowing it, since they move about as fast as high-flying airliners and are easily confused with aircraft lights. A satellite in a "low" orbit (200 to 400 miles high) takes about three minutes to cross the sky from horizon to horizon, but much higher (and much fainter) satellites can take up to half an hour or more. Because most satellites are generally launched into orbit with the same easterly direction as Earth's rotation, they are usually seen moving across the sky on a southwest to northeast or northwest to southeast trajectory.


More than 7,000 satellites and pieces of debris currently orbit Earth. Satellites in very high, geosynchronous orbits form a belt around our planet.

Graphic by Seth Shostak; Photo Researchers, Inc.

If all goes according to schedule, sometime in the middle of this month, *Mir* and the space shuttle *Atlantis* (at an altitude of 245 miles) will dock for the first time. As the docking is carried out, you may be able to see both crafts moving in tandem across the twilight sky like two very bright stars of about magnitude –1. And after docking, the station and the shuttle should appear even brighter, possibly of magnitude –2. Because viewing times and angles will differ considerably from one place to another across North America, and may also change with the launch schedule, look for detailed information on how to view this historic mission in your local news media.

THE PLANETS IN JUNE

Mercury has become a morning object after passing inferior conjunction on the 5th. Your best chance of finding this planet will come on the 26th, when a delicately thin, waning crescent moon, sitting four degrees to the lower left of Mercury and four degrees to the lower right of Venus, forms a broad isosceles triangle with the two. This close gathering may be viewed with binoculars, except perhaps from some northern states, where it might be too low in the brightening dawn. Mercury reaches greatest elongation, twenty-two degrees west of the sun, on the 29th.

Venus will rise shortly before sunrise at about 4:30 A.M. local daylight time—a charming sight against the brightness of the coming day. As Venus continues ahead of us in its orbit, it will disappear behind the sun next month.

Mars is no longer as dazzling as it was during the winter months and now ranks with stars of the first magnitude. The planet's eastward motion carries it away from Regulus and the sickle of Leo, and at month's end, Mars will be setting before midnight, local daylight time.

Jupiter rules the sky, standing at opposition on the 1st, 180 degrees from the sun. You'll find it low in the southeast at dusk, gleaming at magnitude –2.6. As Jupiter moves slowly in its retrograde (westward) motion, it passes 5.5 degrees north of Antares on the 7th. This is the second of three conjunctions between the planet and this bright red star this year.

Saturn, in Aquarius, rises after midnight and is nearly due south by sunrise. It brightens imperceptibly to magnitude 1.2, despite the nearly edge-on appearance of its rings. The moon passes to the north of Saturn on the mornings of the 19th and the 20th.

The **Moon** is at first quarter on the 6th at 6:26 A.M., EDT; full moon is on the 13th at 12:03 A.M., EDT; last quarter is on the 19th at 6:01 P.M., EDT; and new phase is on the 27th at 8:50 P.M., EDT. On June 12 at 9:00 P.M., EDT, the moon arrives at perigee, its closest point to the earth, 221,950 miles away. As a result of this near coincidence of perigee with the full moon, one of the highest tides of the year can be expected.

The summer solstice, marking the first day of summer for the Northern Hemisphere, occurs on June 21 at 4:36 P.M., EDT. At this moment, the sun's rays shine straight down on the Tropic of Cancer, latitude 23.5 degrees north.

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Cosmic Windows

by Neil de Grasse Tyson

The human eye is often advertised as the most impressive of the body's organs. Its ability to focus near and far, to adjust to a broad range of light levels, and to distinguish colors are all at the top of most people's list of eye-opening features. But if one were to take note of the many bands of light that are invisible to us, one would be forced to declare that humans are practically blind. How impressive is our hearing? Bats can clearly fly circles around us with a sensitivity to pitch that extends beyond our own by an order of magnitude. And if the human sense of smell were as good as that of dogs, then Fred, rather than Fido, might be the one sniffing out contraband during airport customs searches.

The history of human discovery is characterized by the desire to extend the senses beyond our inborn limits. It is through this desire that we open new windows to the universe. For example, beginning in the 1960s with the early Soviet and NASA missions to the moon and the planets, computer-controlled space probes, which we can rightly call robots, became (and still are) the standard tool for space exploration. Robots in space have several clear advantages over astronauts: they are cheaper to launch, they can be designed to perform experiments of very high precision without the interference of a cumbersome pressure suit, and since they are not alive in any traditional sense of the word, they cannot be killed in a space accident. But until computers can simulate human curiosity and human sparks of insight, and until they can synthesize information and recognize a serendipitous discovery when it stares them in the face, robots will remain tools designed to discover what we already expect to find. Unfortunately, profound questions about nature lurk among those that have yet to be asked.

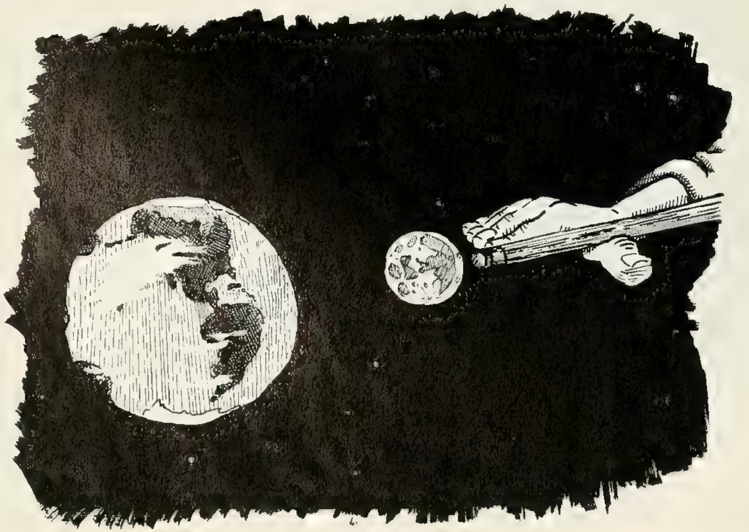
The most significant improvement to our feeble senses is the extension of our sight into the invisible bands of what is collectively known as the electromagnetic spectrum. In the late nineteenth century, German physicist Heinrich Hertz performed experiments that helped to unify conceptually what were previously considered to be unrelated forms of radiation. Radio waves, infrared, visible light, and ultraviolet were all revealed to be cousins in a family of light whose members simply differed in energy. The full spectrum, including all parts discovered after Hertz's work, extends from the low-energy part that we call radio waves and continues in order of increasing energy to microwaves, infrared, visible (comprising the "rainbow seven": red, orange, yellow, green, blue, indigo, and violet), ultraviolet, X-rays, and gamma rays.

Superman, with his X-ray vision, has no special advantage over modern-day scientists. Yes, he is somewhat stronger than your average astrophysicist, but astrophysicists can now "see" into every major part of the electromagnetic spectrum. In the absence of this extended vision, we are not only blind but also ignorant, because the existence of many astrophysical phenomena is revealed through some windows and not others.

What follows is a selective peek through each window to the universe, beginning with radio waves, which require very different detectors from those you will find in the human retina.

In 1932 Karl Jansky, employed by Bell Telephone Laboratories and armed with a radio antenna, first identified radio signals that emanated from somewhere other than Earth: he had discovered the center of the Milky Way galaxy. Its radio signal is so intense that if the human eye were sensitive to radio waves, the galactic center would be among the brightest locations in the sky.

With some cleverly designed electronic equipment, specially encoded radio waves can be transformed into sound. This ingenious apparatus has come to be known as a radio. By virtue of extending our



Blane Bellerud

MS. GONZALEZ'S GEOGRAPHY CLASS HAS GONE TO PIECES.

In an exercise, Marty Gonzalez places her sixth grade geography students in groups to decorate clay pots. Carefully the students paint animals, plants, and landscapes that portray geographic cultures. Afterwards, students proudly submit each of their creations which are put into individual brown bags.

Then Ms. Gonzalez does the only natural thing left to do. She pounds each bag with a hammer, shattering the contents. Only to hand the bags over to different groups of students who face the task of rebuilding the pots and explaining the culture depicted on them.

In effect, the kids become archeologists. But this lesson does more than teach the children the rigors of being an archeologist. They learn how studying archeological artifacts is important in learning the history of a land and the people who lived there.

For her creative approach to teaching, State Farm is pleased to honor Ms. Gonzalez with the Good Neighbor Award and donate $5,000 in her name to Morris Elementary in Cypress, California.

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sense of sight, we have also, in effect, managed to extend our sense of hearing. But any source of radio waves, or practically any source of energy at all, can be channeled to vibrate the cone of a speaker, although this fact is occasionally misunderstood by journalists. For example, when the *Voyager* probes discovered radio emissions from Saturn in the early 1980s, it was simple enough for astronomers to hook up a radio receiver equipped with a speaker. The radio wave signal was then converted into audible sound waves, whereupon one journalist reported that "sounds" were coming from Saturn, and that life on Saturn was trying to tell us something.

With much more sensitive and sophisticated radio detectors than were available to Jansky, we now explore not just the Milky Way but the entire universe. As a testament to our initial seeing-is-believing bias, early detections of radio sources in the universe were often considered untrustworthy until they were confirmed by observations with a conventional telescope. Fortunately, most classes of radio-emitting objects also emit some level of visible light, so blind faith was not always required. Eventually, radio wave telescopes produced a rich parade of discoveries, including the still-mysterious quasars (loosely assembled acronym of "quasi-stellar radio source"), which are among the most distant objects in the known universe.

Gas-rich galaxies emit radio waves from the abundant hydrogen atoms that are present (more than 90 percent of all atoms in the universe are hydrogen). With large arrays of electronically connected radio telescopes, we can generate very high resolution images of a galaxy's gas content, revealing such intricate features in the hydrogen gas as twists, blobs, holes, and filaments. In many ways the task of mapping galaxies is no different from that facing the fifteenth- and sixteenth-century cartographers whose renditions of continents—distorted though they were—represented a noble human attempt to describe worlds beyond their physical reach.

If the human eye were sensitive to microwaves, then this window of the spectrum would enable you to see the radar emitted by the radar gun from the highway patrol officer who hides in the bushes. And microwave-emitting telephone-relay towers would be ablaze with light. Note, however, that the inside of your microwave oven would look no different, because the mesh embedded in the door reflects microwaves back into the cavity to prevent their escape. Your eyeball's vitreous humor is thus protected from getting cooked along with your food.

Microwave telescopes were not actively used to study the universe until the late 1960s. They allow us to peer into cool, dense clouds of interstellar gas that ultimately collapse to form stars and planets. The heavy elements in these clouds readily assemble into complex molecules whose signatures in the microwave part of the spectrum are unmistakable because of their match with molecules that exist on Earth.

Some cosmic molecules are familiar to the household: NH_3 (ammonia), H_2O (water). Some are deadly: CO (carbon monoxide), HCN (hydrogen cyanide).

Some remind you of the hospital: H_2CO (formaldehyde), C_2H_5OH (ethyl alcohol).

And some don't remind you of anything: N_2H^+ (dinitrogen monohydride ion), CHC_3CN (cyanodiacetylene).

About 100 molecules are known, including the recently discovered glycine, which is an amino acid building block for protein and thus for life as we know it. Yes, we are stardust.

Without a doubt, the most important single discovery in astrophysics was made with a microwave telescope. The leftover heat from the big-bang origin of the universe has now cooled to a temperature of about 3° on the "absolute" temperature scale. (The absolute temperature scale quite reasonably sets the coldest possible temperature at 0°, so there are no negative temperatures. Absolute 0° corresponds to about –460° F, while 310° absolute corresponds to room temperature.) In 1965, this big-bang remnant was serendipitously measured in a Nobel Prize-winning observation conducted at Bell Telephone Laboratories by physicists Arno Penzias and Robert Wilson. The remnant manifests itself as an omnipresent and omnidirectional ocean of light dominated by microwaves—hence the commonly used term "3° microwave background." The name is somewhat misleading, however, because the measured temperature is actually closer to 2.7°, and while the light peaks strongly in microwaves, it radiates at all wavelengths.

This discovery was, perhaps, serendipity at its finest. Penzias and Wilson humbly set out to find terrestrial sources that interfered with microwave communications, but what they found was compelling evidence for the big-bang theory of the origin of the universe, which must be

Mrs. Rogers' 4th grade class proved heroes really do live outside comic books.

Last year a group of kids set out on a bold mission. To save the remaining population of California Freshwater Shrimp from extinction.

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like fishing for a minnow and catching a blue whale.

Moving farther along the electromagnetic spectrum, we get to infrared light. Also invisible to humans, it is most familiar to fast-food fanatics whose French fries are kept warm with infrared lamps for hours before purchase. These lamps also emit visible light, but their active ingredient is an abundance of invisible infrared photons that the food readily absorbs. If the human retina were sensitive to infrared, then an ordinary household scene at night, with lights out, would reveal all objects that sustain a temperature in excess of room temperature, such as the household iron (provided it was turned on), the metal that surrounds the pilot light of a gas stove, the hot water pipes, and the exposed skin of any humans who stepped into the scene. This picture is not more enlightening than what you would see with visible light, but you could imagine one or two creative uses of this vision, such as looking at your home in the winter to spot where heat leaks from the windowpanes or the roof.

As a child, I knew that at night, with the lights out, infrared vision would reveal monsters hiding in the bedroom closet only if they were warmblooded. But everybody knows that your typical bedroom monster is reptilian and coldblooded. Infrared vision would thus miss a bedroom monster completely because it would simply blend in with the walls and the door.

In the universe, the infrared window is most useful as a probe of dense clouds that contain stellar nurseries. Newly formed stars are often enshrouded by leftover gas and dust. These clouds absorb most of the visible light from their embedded stars and reradiate it in the infrared, rendering our visible light window quite useless. While visible light gets heavily absorbed by interstellar dust clouds, infrared moves through with only minimal attenuation, which is especially valuable for studies in the plane of the Milky Way galaxy, because this is where the obscuration of visible light is at its greatest. Back home, infrared satellite photographs of Earth's surface reveal, among other things, the paths of warm oceanic currents, such as the North Atlantic Drift current that swirls round the British Isles (which are farther north than the entire state of Maine) and keeps them from becoming a major ski resort.

The energy emitted by the sun, whose surface temperature is about 5,800° absolute, peaks in the visible part of the spectrum, as does the sensitivity of the human retina, which is why our sight is so useful in the daytime. If this spectral match were not so, then we could rightly complain that some of our retinal sensitivity was wasted. We don't normally think of visible light as penetrating, but light passes mostly unhindered through glass and air. Ultraviolet, however, is summarily absorbed by ordinary glass, so glass windows would not be much different from brick walls if our eyes were sensitive to only ultraviolet.

Stars that are more than three or four times hotter than the sun are prodigious producers of ultraviolet light. Fortunately, these stars are also bright in the visible part of the spectrum, so discovering them has not depended on access to ultraviolet telescopes. The ozone layer in our atmosphere absorbs most of the ultraviolet, X-rays, and gamma rays that impinge upon it, so a detailed analysis of these hottest stars can best be obtained from Earth orbit or beyond. These high-energy windows in

A new era begins. The Dinosaur
American Museum

the spectrum thus represent relatively young subdisciplines of astrophysics.

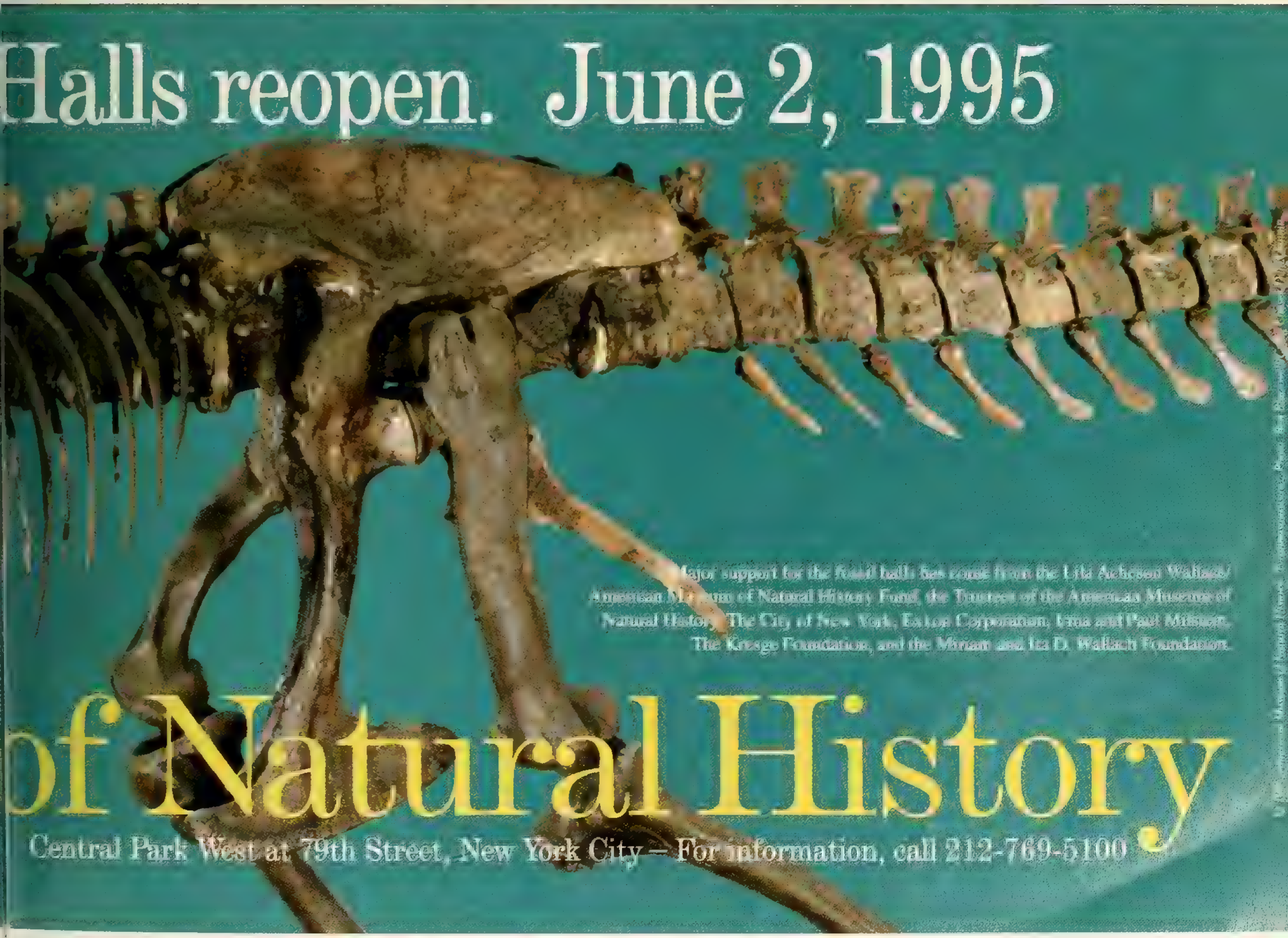
As if to herald a new century of extended vision, the first Nobel Prize ever awarded in physics went to German physicist Wilhelm C. Röentgen in 1901 for his discovery of X-rays. Both ultraviolet and X-rays can reveal the presence of one of the most exotic objects in the universe: black holes. Black holes emit no light—their gravity is too strong even for light to escape—so their existence must be inferred from the energy emitted by matter that might spiral onto its surface from a companion star. The scene resembles what water looks like as it spirals down a toilet bowl. At temperatures more than twenty times that of the sun's surface, ultraviolet and X-rays are the predominant forms of energy released by material just before it descends into a black hole.

Discovering something does not require that you understand, either in advance or after the fact, what it is you have discovered. This happened with the 3° microwave background, and it is happening now with gamma ray bursts. The gamma ray window has revealed mysterious, seemingly random bursts of high energy scattered across the sky. Their discovery was made possible through the use of space-borne gamma ray telescopes, yet their origin and cause remain unknown.

If we now broaden the concept of vision to include the detection of subatomic particles, then we get to use neutrinos. The elusive neutrino is a particle that is formed every time a proton transforms into an ordinary neutron and a positron (the antimatter partner to an electron). As obscure as the process sounds, it happens in the sun's core about 100 billion billion billion billion (10^{38}) times each second. Neutrinos then pass directly out of the sun as if it were not there at all. A neutrino "telescope" would allow a direct view of the sun's core and its ongoing thermonuclear fusion, which no band from the electromagnetic spectrum can reveal. But neutrinos are extraordinarily difficult to capture because they hardly ever interact with matter. So an efficient and effective neutrino telescope is a distant dream.

The detection of gravity waves, another elusive window on the universe, would reveal catastrophic cosmic events. But as of this writing, gravity waves, predicted in Einstein's general theory of relativity of 1916 as "ripples" in space and time, have never been detected from any source. Physicists at the California Institute of Technology plan to develop a specialized gravity-wave detector that consists of an L-shaped evacuated pipe with two-and-a-half-mile-long arms housing laser beams. If a gravitational wave passes by, the light path in one arm will temporarily differ in length from that of the other arm by a tiny amount. The experiment is known as LIGO, the Laser Interferometer Gravitational-wave Observatory, and it will be sensitive enough to detect gravitational waves from colliding stars over 100 million light-years away. One can imagine a time in the future when gravitational events in the universe—collisions, explosions, and collapsed stars—will be routinely observed this way. Indeed, we may one day open this window wide enough to see beyond the opaque wall of microwave background radiation to the beginning of time itself.

Neil de Grasse Tyson is an astrophysicist with a joint appointment at the American Museum–Hayden Planetarium and Princeton University.



Halls reopen. June 2, 1995

Major support for the fossil halls has come from the Lila Acheson Wallace/American Museum of Natural History Fund, the Trustees of the American Museum of Natural History, The City of New York, Exxon Corporation, Irma and Paul Milstein, The Kresge Foundation, and the Miriam and Ira D. Wallach Foundation.

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Dinos

How We Know What We Know

by Michael Novacek

Senior Vice President and Provost, American Museum of Natural History

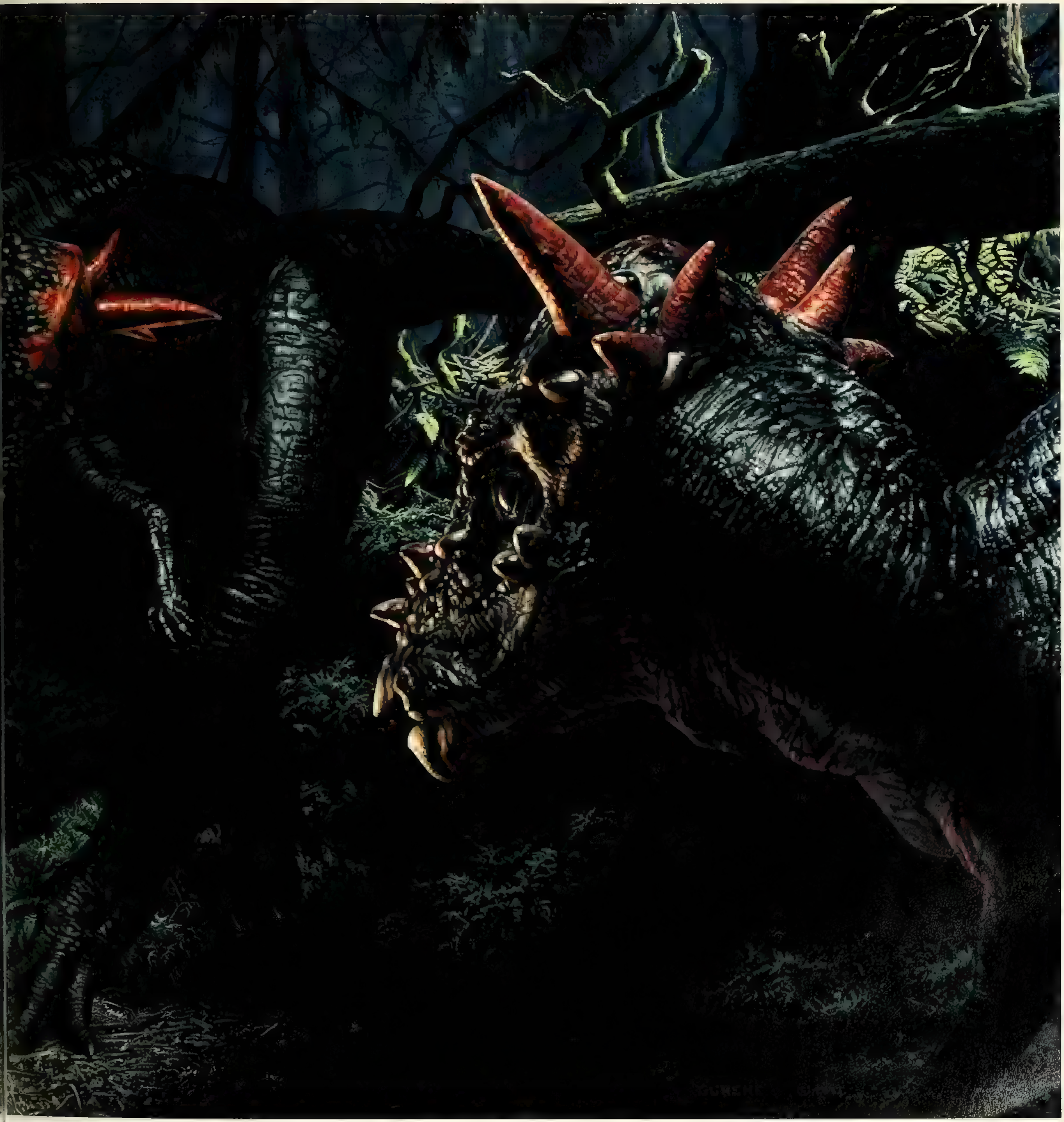
Dinosaurs claim a special place in the 3.5-billion-year history of life. They represent the glories of evolution, the flourishing of an ancient biological empire, and the mysteries of mass extinction in a way that inspires students of all ages. No less dramatic are the new insights about dinosaurs that represent the fruits of scientific labor. Recent finds demonstrate that the golden age of discovery continues. Much of our knowledge still comes from fossil bone. We can dissect that bone and study its microstructure for clues to dinosaur thermoregulation, and when samples of bones are abundant, we can decipher sex ratios, growth profiles, and population structure. We can pursue other clues provided by trackways, eggs and embryos, and even coprolites. Our better techniques for untangling the patterns of descent and divergence provide a powerful framework for understanding dinosaurs and suggest that in one sense, dinosaurs never went extinct at all: the descendants of at least one dinosaur lineage live among us as birds. A showcase for this renaissance in paleontology is being unveiled this June, when the halls of the dinosaurs reopen at the American Museum of Natural History. With 85 percent of the skeletons on display consisting of actual bones, rather than casts, the exhibition is the world's premier collection of dinosaur fossils. The essays in this special issue have, then, a twofold purpose. They capture the excitement and range of *au courant* "dinosaurology," and they also herald the opening of the new halls, a great event in science and in public education. Several of the authors in this issue were intimately involved in the renovation of these halls. I share with them the joy of being part of this process.

Two Stygimoloch *prepare to engage in a head-butting contest. These herbivorous, bone-headed dinosaurs lived in North America during the late Cretaceous.*

Illustration by John Gurche

aurs

A special section prepared
by Judy A. Rice



Roots of the Family Tree

by Paul C. Sereno

The rugged Ischigualasto valley lies at the foot of the Andes in northwest Argentina. In 1988 I traveled to Ischigualasto hoping to uncover the remains of early dinosaurs. Some thirty years before, Alfred Romer, a paleontologist from Harvard, had found a cache of bones in Triassic sediments, some 200 million years old, on the valley floor. These fossils recorded vertebrate life on the very eve of the dinosaur era. Argentine paleontologists soon followed and excavated many additional fossils, including a partial skeleton of an early dinosaur they called *Herrerasaurus*.

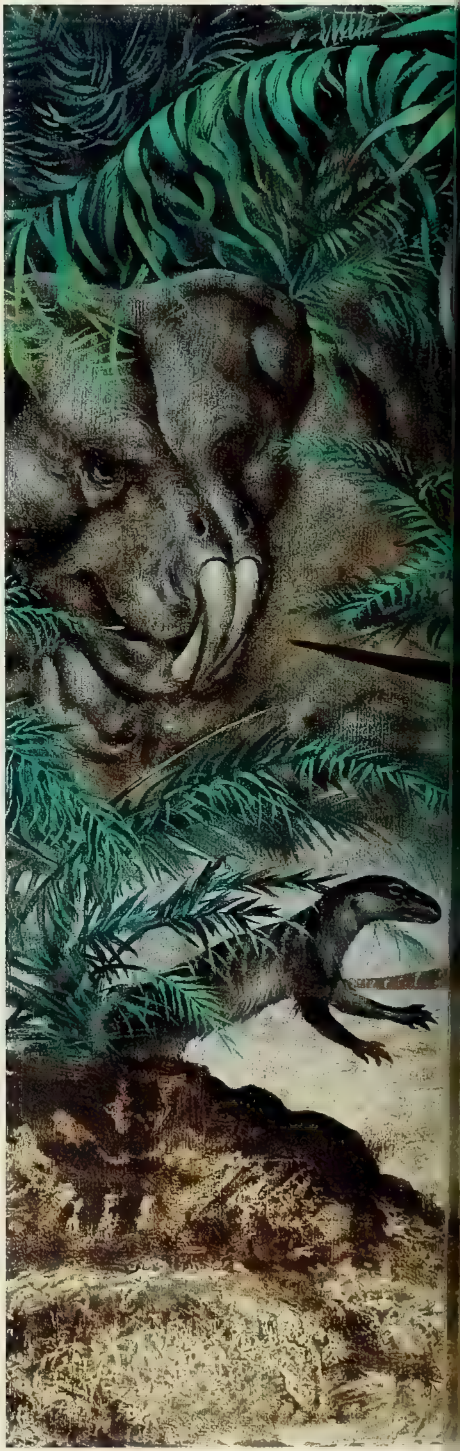
Over the years, the fragmentary skeleton of *Herrerasaurus* has posed more questions than it has answered. Is this creature really a dinosaur? How do we decide, scientifically, what is, or is not, a dinosaur? Other, broader questions arose regarding the large-scale changes that had inaugurated the dinosaur era, but the headless remains of *Herrerasaurus* offered no further insights.

I decided to assemble a team of paleontologists and students and to go to Ischigualasto because it is one of the few places on earth that preserves fossils spanning the time period during which dinosaurs originated and came to dominate their world. The rocks in this region are tilted about ten degrees and then cut off at the surface by erosion. As a result, successive ridges record successive pages of Triassic time. Along one edge of the Ischigualasto valley, the rocks predate the appearance of dinosaurs, while the red cliffs on the other side of the valley entomb dinosaurs that flourished during their time and can be found worldwide. I believed that the story of the origins and rise of dinosaurs lay in between these landforms, locked in rocks on the valley floor.

After three weeks of prospecting, we hit pay dirt. In a little side valley we had not yet surveyed, I spied some fossil bone on a sandstone ledge. As I looked closer, I saw a connected series of long neck bones and followed these to the top of a skull emerging from the rock, the first skull of an early dinosaur ever found.

As the skeleton was being cleaned, my Argentine colleague Fernando Novas and I were able to match several of its bones with those in the original *Herrerasaurus* material, confirming that it was the same kind of creature. The new parts—skull and forelimb—had some surprising features. The lower jaws, for example, had a polished sliding mechanism halfway along their length that allowed them to bend around prey trapped between the upper and lower jaws. In some living lizards, a similar mechanism is believed to be an adaptation for handling live prey, and we concluded that it served the same function in *Herrerasaurus*. The hand had only three main fingers terminating in sickle-shaped claws. The most unusual adaptation in the hand, however, was a series of deep pits near the knuckles. The first bone in each of the fingers fitted into these pits when they were fully retracted. We then understood that these pits functioned as mechanical stops and that the hand was designed for slashing.

The more complete picture of *Herrerasaurus* that emerged from the new fossils provided clues to where this creature fits in the scheme of dinosaur evolution. One theory held that *Herrerasaurus* was on the stem leading to all later dinosaurs—an ancestral dinosaur of sorts that lay outside any of the conventional dinosaur subgroups that soon evolved, such as the ornithischians, prosauropods, and theropods. As Fernando Novas and I continued our comparisons, we soon realized that all carnivorous dinosaurs (or theropods) had flexible lower jaws with an extra joint made of the same bones as in *Herrerasaurus*. Theropod hands, moreover, showed the characteristic knuckle pits. We were able to see other unusual



similarities between theropods and *Herrerasaurus* in other parts of the skeleton, such as the swollen end of the pubic bone and the stiffened distal half of the tail. This evidence confirmed that *Herrerasaurus* wasn't a stem dinosaur but represented a very early stage in the evolution of theropod dinosaurs.

In 1991, we returned to the valley. Among the many rock layers, we hoped to find evidence of an ash bed from a volcano that had erupted at the time *Herrerasaurus* lived. Radioactive elements locked in these crystals could give us an exact age for the layer and for any fossils found nearby, and thus give us a chronological key to our finds. We crawled across, and examined, hundreds of layers of rock. Finally, Ray Rogers, an American student, found the ash, a greenish layer with a popcornlike texture, just a stone's throw from the *Herrerasaurus* site. Tiny, shining crystals in this layer had solidified in the course of a volcanic eruption in the Andes

At the dawn of the age of dinosaurs, a pack of small cynodonts harass the predatory Herrerasaurus, *while two herbivores—a rhynchosaur and a dicynodont—rummage in the vegetation. One of the earliest theropod dinosaurs,* Herrerasaurus *lived some 228 million years ago in what is now South America.*

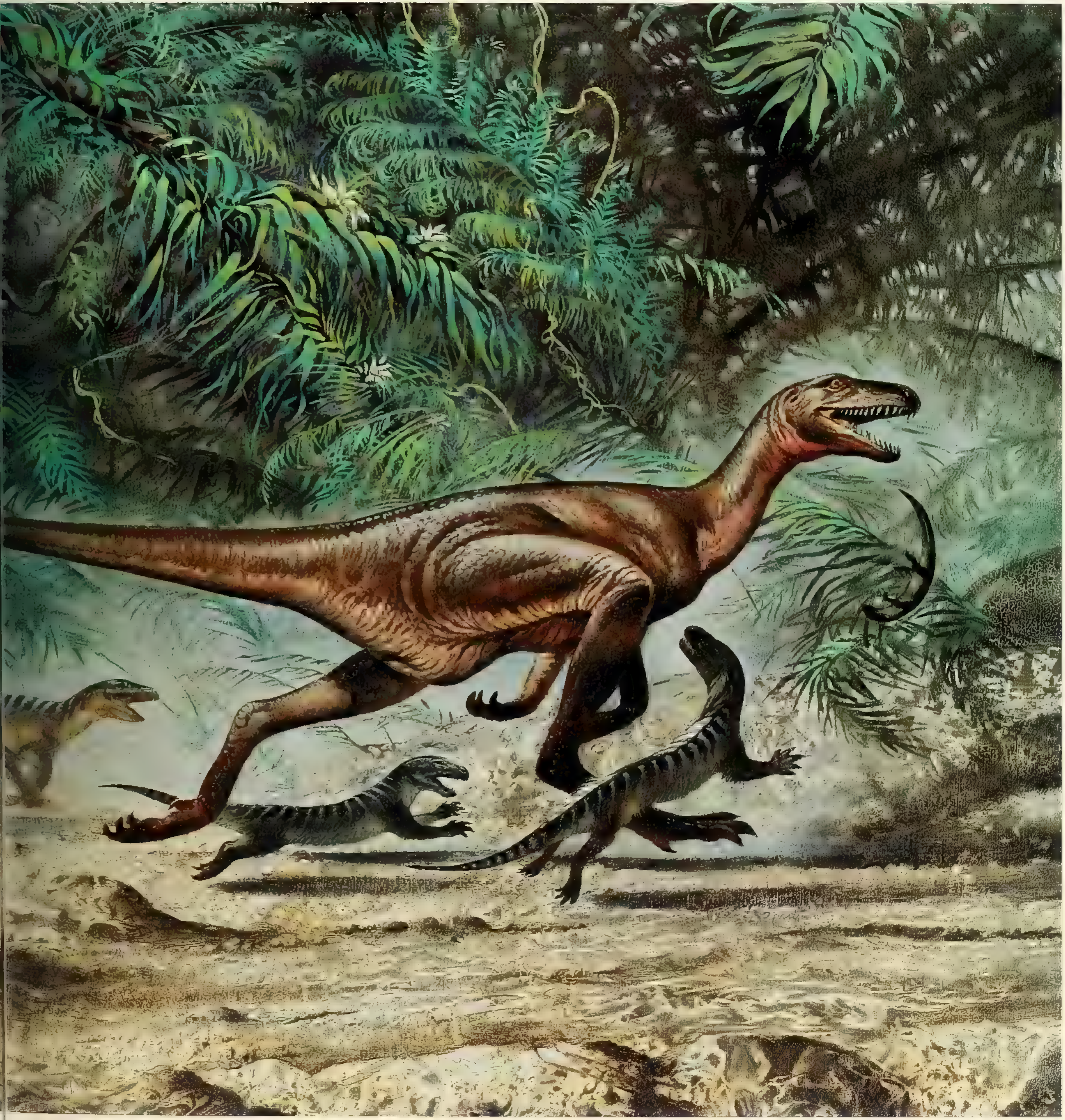


Illustration by John Barber; *The Book of Life*, Ebury Press, 1993

and had showered the land surface. When analyzed, the ash proved to be 228 million years old.

Working not far from the spot where we had discovered the *Herrerasaurus* skeleton, Ricardo Martinez, an Argentine student, picked up a softball-sized rock and noticed two teeth on one side. Realizing he may have decapitated a small reptile skeleton, he carefully replaced the rock. As we assembled around the new find, we could discern the outlines of the skeleton; the forelimb was less than half the length of the hind limb, indicating that it belonged to a biped. We agreed that it was the skeleton of a previously unknown dinosaur, one measuring less than four feet from snout to tail tip.

Like *Herrerasaurus,* this creature was a predator, with knuckle pits, a slashing hand, and sharp claws. But it lacked the extra jaw joint and the swollen pubic bone. The skeleton represented a more primitive line of theropod evolution, one that must have branched off before the other specializations arose. We called the new dinosaur *Eoraptor,* or "dawn predator." More than that of any other early species discovered, its anatomy approaches what we believe the anatomy of the common ancestor of all dinosaurs to have been.

Now with our fossil sites in chronological order and the ash section calibrated at 228 million years, we could look for the first time at the waxing and waning of the various fossil reptiles found in the sediments on the valley floor, which were all laid down over several million years. Were dinosaurs becoming more common as we approached the red cliffs? The traditional explanation for the dinosaurs' rise to dominance was that the upright posture and other adaptations of all early dinosaurs gave them an advantage over sprawling reptiles; they simply outcompeted their rivals over millions of years. Now we could test this scenario.

A cleaned Herrerasaurus *skull, the first complete skull of an early dinosaur ever excavated, sits atop Triassic sediments in Argentina's Ischigualasto valley.*

Paul C. Sereno

Our tally of specimens revealed that dinosaurs were not becoming more common in the younger sediments on the valley floor. In fact, all our records of *Herrerasaurus* (fifteen bones and partial skeletons in all) and the sole record of *Eoraptor* were located low in the section in the oldest layers. Other reptile groups, such as the lizardlike rhynchosaurs and mammallike cynodonts, remained abundant after the early dinosaurs disappeared. The eventual extinction of these reptiles and the rise of later dinosaurs, at least in this part of the ancient world, happened more quickly and later than originally thought. The record of this change is now compressed into a narrower band of rock at the base of the red cliffs.

The eventual success of dinosaurs can thus no longer be tied to the most obvious adaptations among their earliest representatives. The flexible jaw and slashing hands of theropods had already evolved by the time the first sediments in Ischigualasto were laid down, several million years before dinosaurs rose to dominance. Likewise, early work in the valley by Argentine paleontologists had turned up the partial skeleton, including a jaw fragment, of an herbivorous ornithischian dinosaur known as *Pisanosaurus,* indicating that, although rare, dinosaurs with specializations for plant eating had also evolved by this time.

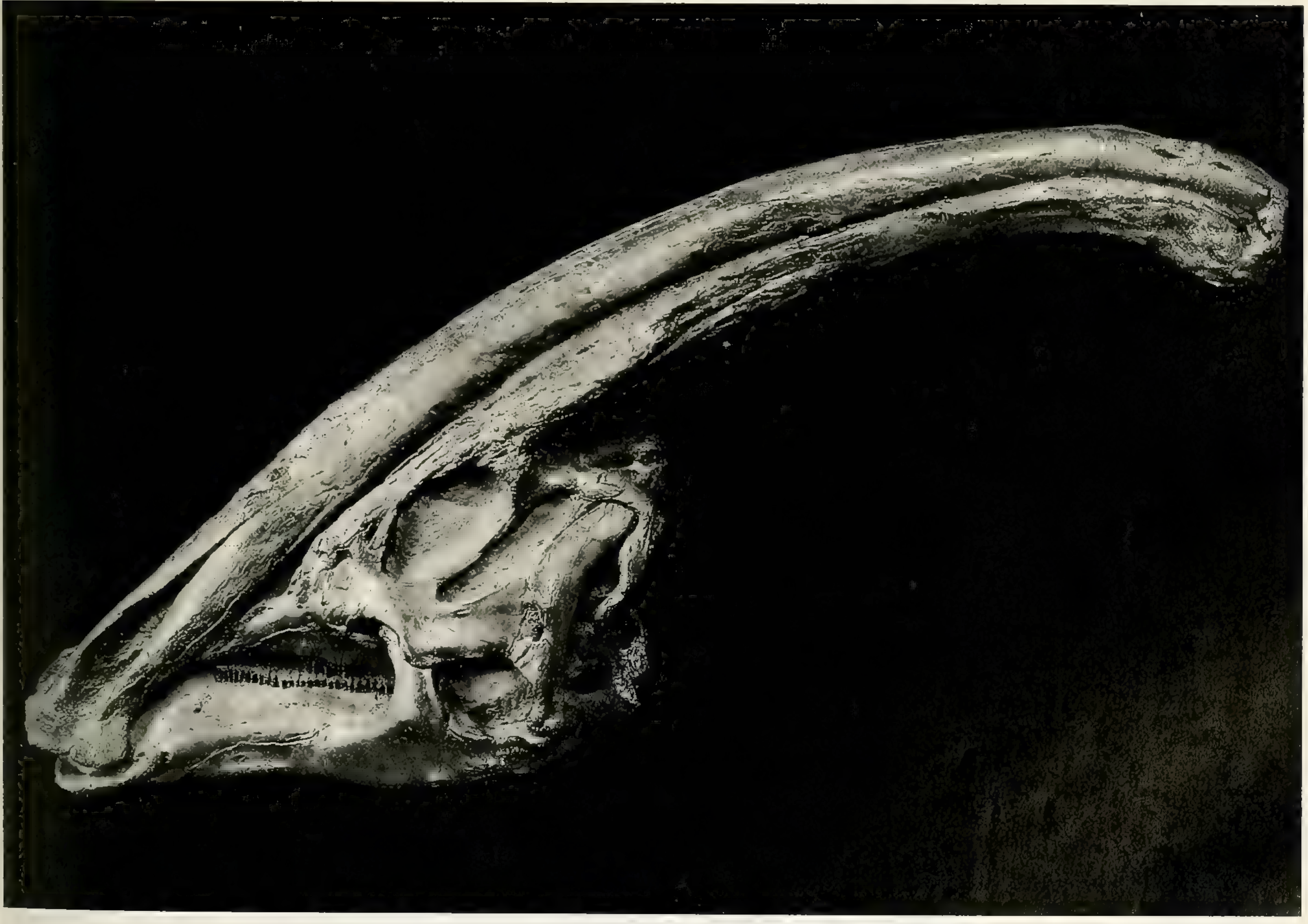
The reason that dinosaurs rose to dominance 225 million years ago may be as difficult to pin down as the reason for their extinction at the end of the Cretaceous, 160 million years later. If there is no temporal connection between the initial diversification and early specializations of dinosaurs and their domination of terrestrial communities, perhaps their ascendancy was as accidental as their decline. Exactly what happened when the last sediments in the Ischigualasto valley were being deposited remains unclear. But during this relatively short period of time, dinosaurs appear to have seized an opportunity they might never have relinquished, had not chance intervened once again.

Why Cladistics?

by Eugene S. Gaffney, Lowell Dingus, and Miranda K. Smith

In June 1995, an array of dinosaurs absent from the exhibition halls of the American Museum of Natural History for three long years will reappear. The renovation of the two halls that will house these magnificent examples from the Museum's collection has involved much more than refurbishing the surroundings and placing the dinosaurs in more dynamic, realistic poses. The halls now reflect the newest and most rigorously tested scientific perspective on these creatures and their evolution. The old Halls of Early and Late Dinosaurs—organized as a "walk through time"—have been replaced by the Hall of Saurischian Dinosaurs and the Hall of Ornithischian Dinosaurs, which offer the visitor a chance to explore the many-branched dinosaur family tree. Rather than juxtaposing creatures that lived at the same time, we have grouped them according to their evolutionary relationships. Thus, stegosaurs, duckbills, and ankylosaurs are among the dinosaurs in the ornithischian hall, while giant sauropods, bipedal carnosaurs, and birds—the latter being the living representatives of the dinosaur line—contribute to the variety of the saurischian hall. The American Museum is the first institution to present a major exhibition based on cladistics, the best current scientific method for reconstructing evolutionary relationships.

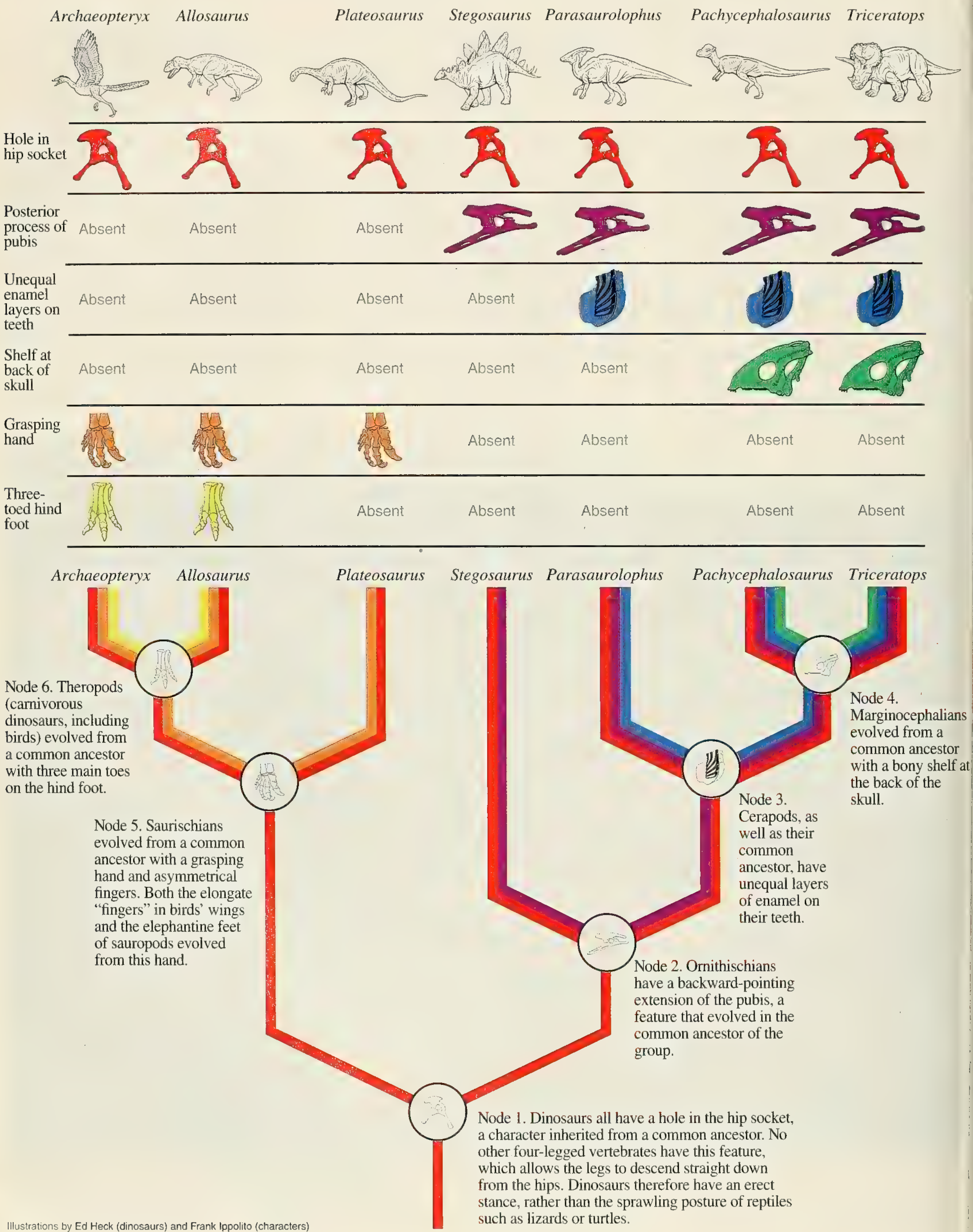
Also called phylogenetic systematics, cladistics is a method of determining the evolutionary relationships of organisms—both living and extinct. It was developed about forty years ago by a German entomologist, Willi Hennig. In the late 1960s,



Forming a tubelike crest, the elongated nasal passages of Parasaurolophus *are its most prominent feature. But a better clue to its place on the dinosaur family tree lies in its tooth enamel.*

Denis Finnin; AMNH

Building a Cladogram


Archaeopteryx
Allosaurus
Plateosaurus
Stegosaurus
Parasaurolophus
Pachycephalosaurus
Triceratops
Hole in hip socket
Posterior process of pubis
Absent
Absent
Absent
Unequal enamel layers on teeth
Absent
Absent
Absent
Absent
Shelf at back of skull
Absent
Absent
Absent
Absent
Absent
Grasping hand
Absent
Absent
Absent
Absent
Three-toed hind foot
Absent
Absent
Absent
Absent
Absent
Archaeopteryx
Allosaurus
Plateosaurus
Stegosaurus
Parasaurolophus
Pachycephalosaurus
Triceratops

Node 6. Theropods (carnivorous dinosaurs, including birds) evolved from a common ancestor with three main toes on the hind foot.

Node 5. Saurischians evolved from a common ancestor with a grasping hand and asymmetrical fingers. Both the elongate "fingers" in birds' wings and the elephantine feet of sauropods evolved from this hand.

Node 4. Marginocephalians evolved from a common ancestor with a bony shelf at the back of the skull.

Node 3. Cerapods, as well as their common ancestor, have unequal layers of enamel on their teeth.

Node 2. Ornithischians have a backward-pointing extension of the pubis, a feature that evolved in the common ancestor of the group.

Node 1. Dinosaurs all have a hole in the hip socket, a character inherited from a common ancestor. No other four-legged vertebrates have this feature, which allows the legs to descend straight down from the hips. Dinosaurs therefore have an erect stance, rather than the sprawling posture of reptiles such as lizards or turtles.

Illustrations by Ed Heck (dinosaurs) and Frank Ippolito (characters)

under the leadership of curator Gareth Nelson, the American Museum became a center for the further development and practice of this new methodology. During the past two decades, cladistics has come to dominate the study of evolutionary relationships and has had profound effects on the way in which scientists worldwide attempt to solve biological problems, from the origin of birds to the geographic distribution of animals. By putting the fossils into a cladistic context, the new exhibition halls exemplify the research in which scientists at the American Museum are currently engaged.

Cladistics differs from older methods of reconstructing evolutionary relationships by using the distribution of features, called shared derived characters, to test relationships. We look for patterns of features present in different animals. This distribution of characters usually forms a hierarchy of nested groups, with smaller groups contained within larger ones. For example, the group designated "dinosaurs" is contained within the larger group "vertebrates," because dinosaurs, along with all other vertebrates, have a backbone. The backbone is known as a shared derived character for the group called vertebrates. Each group, or clade, is defined by a set of such shared derived characters inherited from a common ancestor.

Although this is not a perfect method (all scientific probing is subject to criticism and testing), cladistics is more reliable and objective than using the age of fossils, or their occurrence in particular layers of rock, to determine relationships. For example, cladistic analyses show that birds evolved from a small, carnivorous dinosaur, probably very like *Deinonychus* or *Velociraptor*. These dinosaurs, which belong to a group called dromaeosaurs, lived in the Cretaceous, between 107 million and 72 million years ago. Yet the oldest-known bird, *Archaeopteryx,* lived in the late Jurassic, about 140 million years ago. If we relied on relative geological age, we might conclude that the earliest birds gave rise to animals like *Deinonychus* and *Velociraptor*, rather than the other way around. Cladistic analysis indicates that the fossil record is probably not complete and that an animal very similar to *Deinonychus* gave rise to both the birds and later to the dromaeosaurs, including *Deinonychus* and *Velociraptor*. However, we have yet to find fossils of this creature. By using characters in cladistic analyses, we can test hypotheses about phylogenies, or family trees, but we do not seek to specify ancestors and descendants. We only hypothesize which animals are most closely related to each other. While using the geological age of fossils does not result in the most reliable phylogenies, it does provide an important context in which phylogenies can be placed. With cladistics, we thus have a much more realistic and objective view of where evolutionary lineages fit within geological time and where gaps exist in the fossil record of these lineages.

An example of how cladistics works can be seen in the chart on the opposite page. We have chosen seven genera that represent a wide range of dinosaurs. (In an actual study, we would choose as many genera as are represented by good fossil specimens.) Which features, or characters, do we use to determine the evolutionary relationships of these dinosaurs? For living animals, we can look at genetic, chemical, and even behavioral characters, but for fossils, we are limited to the morphology of the skeleton. Even within this limitation, however, we find numerous characters, so which do we choose to work with? Many characters are too limited in distribution; for example, "armor" is found in only one of our representatives (*Stegosaurus*) and therefore gives no clues as to relationships among these particular dinosaurs. A character such as "four limbs" is found in all dinosaurs, as well as in many other animals, and thus is too widespread to be informative. A search for characters with more restricted distributions greatly reduces the number of potentially useful ones.

For simplicity, the chart here has only six characters, but in an actual study, we would use between twenty and one hundred characters to decipher evolutionary relationships. In the Museum's two new dinosaur halls, we have selected a single, derived character for each group. This character is represented by a model that can be touched by the visitor.

By carefully comparing skeletons and charting character distributions, we are looking for patterns of characters that repeatedly form the same group. Computer programs are available to assist with this search. In almost every study, conflicting distributions of characters require the investigator to reexamine specimens and answer such questions as whether the specimens are well enough preserved and whether the characters are really the same, not just similar in appearance. The set of relationships is then depicted graphically in a cladogram. The cladogram that is supported by the greatest number of characters is chosen as the best one, but only as the best one for further work, not as the best and last. Nothing is ever final in science; new theories are proposed, many are rejected, and a few are adopted but remain subject to scientific testing. Cladograms, including those within the new halls, are subject to such testing and may be only temporarily the best.

Those features that define larger groups are called primitive because they are thought to have evolved earlier, whereas features shared by smaller groups evolved later and are called derived, or advanced. Used in this way, the terms primitive and advanced are relative and do not imply that one feature is any better than another. In our chart and cladogram, the character "hole in hip socket" defines the group Dinosauria, which contains all dinosaurs, including birds. Within all vertebrates, having a "hole in hip socket" is unique to the Dinosauria, and we say that it is derived with respect to other vertebrates. But when we are studying subgroups within the dinosaurs, this character is termed primitive. Similarly, four of our dinosaur examples, which form the group Ornithischia, are united by the derived character "posterior process of pubis," that is, a backward-pointing extension of the pubic bone. Within the ornithischians, however, this character is relatively primitive, that is, it evolved early on.

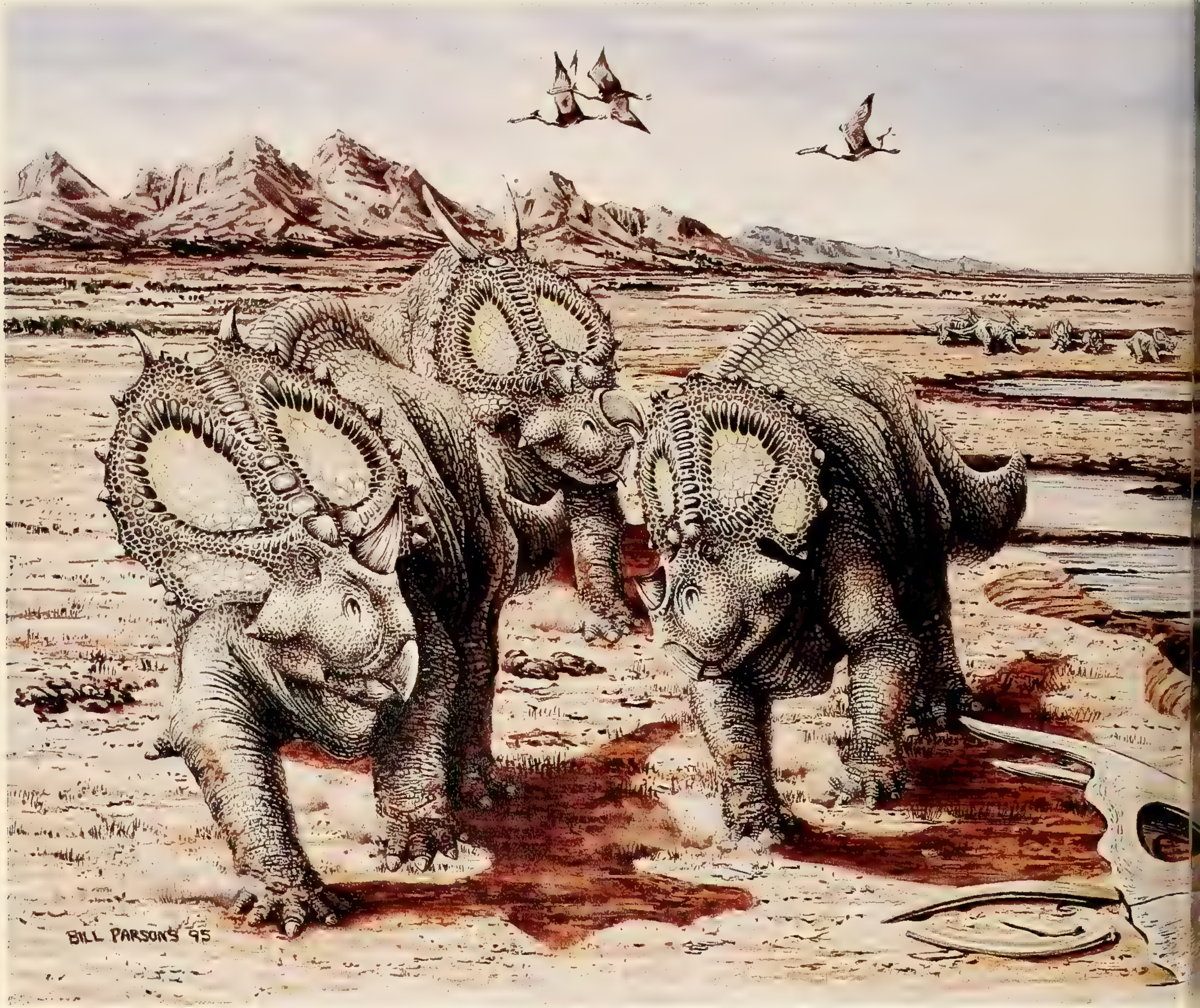
While groups such as mammals and fishes have been the subject of much cladistic analysis, relatively few such studies have been done to establish evolutionary relationships among dinosaurs. Rather, popular interest in dinosaurs has led to numerous studies of their lifestyles and behavior, which in many cases are speculative, rather than based on hard evidence. Although cladograms are often changing as new fossil discoveries are made and our understanding of relationships becomes more refined, cladistic methodology is a good, objective method for testing the paths of evolution. No other museum has the richness and diversity of dinosaur fossils now on display at the American Museum of Natural History. Seeing this collection in a cladistic context emphasizes the real knowledge that can be obtained from fossils.

Horns, Herds, and Hierarchies

by Scott D. Sampson

"Death opens unknown doors." These words, written by British poet John Masefield, could serve admirably as the motto of paleontology. For scientists who scrutinize the remains of long-dead creatures, death does indeed open doors to our understanding of past life. At the risk of sounding morbid, I would add that if one death can offer unexpected insights, many deaths can be a veritable bonanza.

The fossil record abounds with examples of mass deaths, particularly among invertebrates. Although far more rare among backboned animals, mass deaths are also known in a broad range of terrestrial vertebrates, including many dinosaurs. These remarkable "bone beds" can contain tens, hundreds, or even thousands of individuals, with the remains often dominated by what appears to be a single species. The deaths have been attributed to various environmental assailants, including drought, flood, and volcanism. In many instances, they appear to have taken



place over a relatively short time span, ranging from hours to months. Thus, the entombed animals most likely represent a single species, perhaps even a single population—truly a snapshot in time.

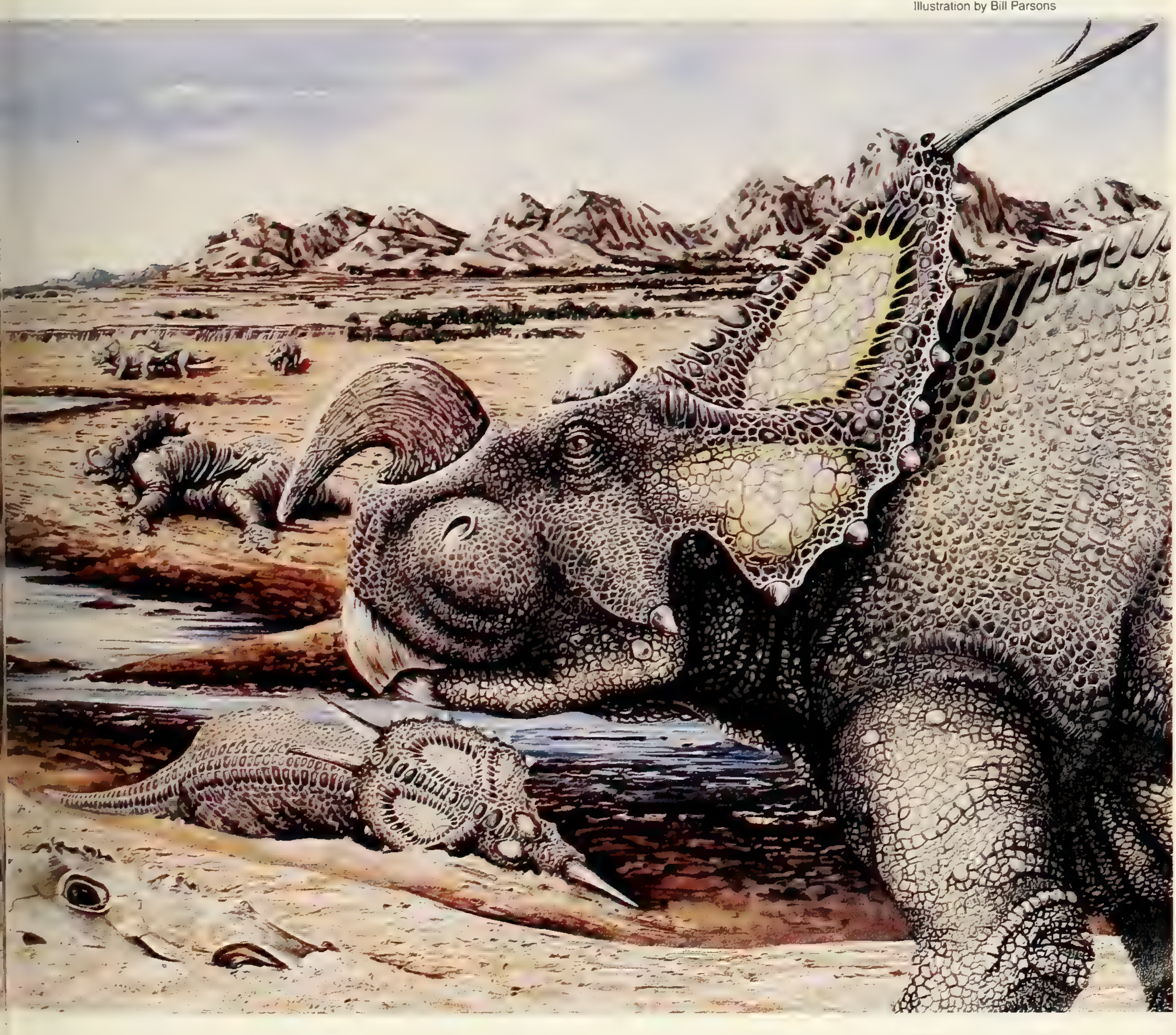
Skeletons preserved in bone beds tend to be disconnected and jumbled; a thigh bone of one animal may lie next to the skull of another. But what these sites may lack in completeness is far outweighed by the sheer amount of information offered by so many specimens. Given a choice between a single, complete, articulated skeleton of a previously unknown dinosaur and a bone bed containing tens or hundreds of disarticulated skeletons of that same animal, many paleontologists, myself included, would opt for the latter. Beyond the joy of pure volume, the reason for this choice is variation. The great majority of all dinosaur species are known from only one or two specimens. Therefore, mass death assemblages, although an unlucky event for the dinosaurs involved, are a boon for paleontology, providing direct insight into variation among and within species.

In 1989, as part of my doctoral research, I worked in two bone beds on the Blackfeet Reservation in northwestern Montana, close to the Canadian border. The site, called Landslide Butte, is an exquisite pocket of badlands carved out of the surrounding prairie by the Milk River. The sediments at Landslide Butte are of late Cretaceous age, about 74 million years old, and rich in dinosaur fossils. Surprisingly, the most common fossils in the area are dinosaur eggshells; the hills are littered with small shards of shell, turned a distinctive black color by millions of years of burial. My primary interest, however, involved larger quarry: ceratopsid, or horned, dinosaurs.

Several years earlier, crews led by paleontologist Jack Horner, of the Museum of the Rockies, in Bozeman, Montana, had found the pair of bone beds, a mile apart, preserving the remains of a rather bizarre horned dinosaur. The vast majority of bones at both sites seemed to belong to the same species. The adult skulls, more than

As drought shrinks their water hole and local forage dwindles, two adult Einiosaurus *(at right and at left, center) and two adolescents (at left, foreground) survey dead and dying herd members.*

Illustration by Bill Parsons

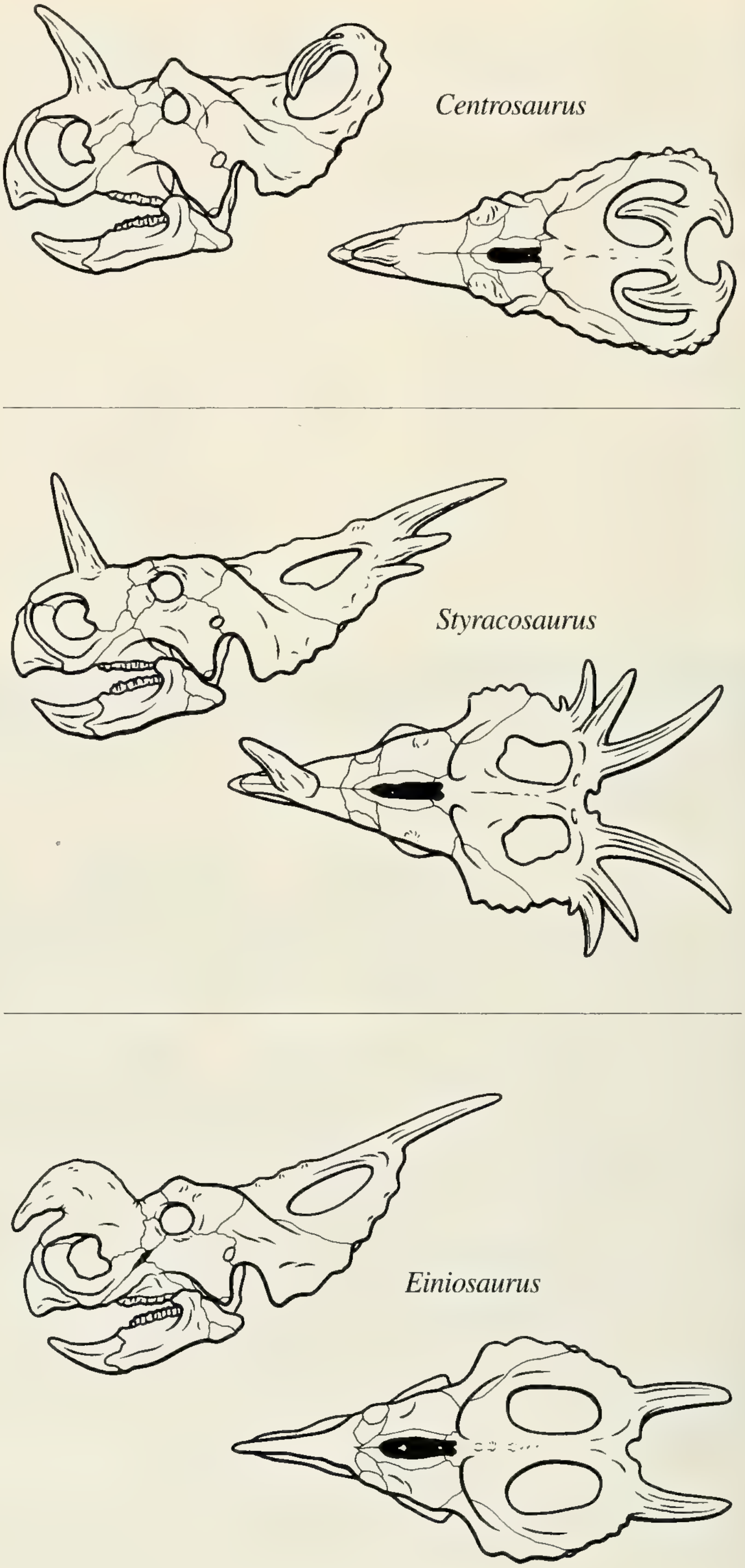


five feet long, have a pair of long spikes that project backward from the bony frill, as well as a rounded horn over each orbit, or eye socket. But the strangest feature is a large, hooked nasal horn, curved so far forward as to be reminiscent of a can opener.

Like other bone beds, these sites contained a bounty of fossils, representing animals that ranged in age from juvenile to adult. One square meter alone contained forty-two different complete or partial bones piled randomly atop one another, turning the dig into a large-scale version of pickup sticks. The entombing sediments were made up of silty mud, remnants of a once expansive floodplain. My colleague Ray Rogers has argued that these sites, and others like them, formed during ancient droughts. The herbivorous horned dinosaurs may have gathered around water holes during extended dry periods and succumbed as local food supplies were depleted. Many of the fossils are fragmentary and scratched, suggesting that the bones were trampled by other dinosaurs, perhaps animals that returned to the site in subsequent seasons. This hypothesis is supported by observations of large mammals living today in East Africa, which are known to die en masse near water holes during droughts. Elephants, for example, will remain close to a dwindling water supply rather than leave it to forage; many eventually die, not of thirst, but of starvation.

The two bone beds yielding the hook-horned beasts occupy approximately the same stratigraphic level, suggesting that, if not contemporaneous, they were formed within several years of each other. A third site, found in the same field area but somewhat higher in the rock section, contained only three animals. These horned dinosaurs have a twin-spiked frill, similar to that of the hook-horned animals, but instead of nasal or orbital horns, they have well-developed bosses (ridged and gnarly surfaces) over the front half of the skull. When these dinosaurs were alive, the bosses were likely covered with some kind of horny, or keratinous, sheath, akin to the horn coverings of modern sheep and antelope. Similar bosses are known in only one other horned dinosaur, *Pachyrhinosaurus,* found in Alaska and in Alberta, Canada.

As both of these bizarre ceratopsids were previously unknown, I had the pleasure of assigning them names. The di-



A sampler of ceratopsian skulls (seen in top and profile views) hints at the great variation in their horns and frills. These skull features, many found only in adult animals, allow paleontologists to distinguish species of horned dinosaurs.

Illustrations by Ed Heck

nosaur with the forward-curving nose horn became *Einiosaurus*, meaning "buffalo lizard" (after the Blackfeet word for buffalo, "eini"). I called the second animal *Achelousaurus*. In Greek mythology, Achelous was a river god who could change his shape at will. In order to fight Heracles, Achelous transformed himself into a bull. Heracles won the battle only after he tore off one of Achelous's horns (incidentally spawning the term "cornucopia," or horn of plenty). The appellation is appropriate because this so-called horned dinosaur apparently lost its horns; that is, it evolved from horned ancestors. *Achelousaurus* is also somewhat of a shape changer, possessing distinctive features of at least two other horned dinosaurs: the frill of *Einiosaurus* and the bosses of *Pachyrhinosaurus*.

Together with two colleagues, Michael Ryan and Darren Tanke, I examined fossils from several other ceratopsian bone beds in Alberta, Canada. As a result of this study, we were able to document skull variation in one of the two major groups of horned dinosaurs, the centrosaurines. (The other group, the most famous member of which is *Triceratops*, is known as chasmosaurines.) We now have a better understanding of how skull shapes changed as horned dinosaurs grew. All juvenile centrosaurines look very similar, with simple, unadorned skulls. Subadult, or adolescent, centrosaurines have adult-sized skulls, but like juveniles, they lack the various elaborate horn and frill shapes of adults. For example, subadults have a narrow nasal horn core that is either erect or curved slightly backward. Only after an animal reached adult size did its skull acquire the characteristic adornments, ranging from horn cores—of variable size, shape, and orientation—to thickened bosses. In contrast to *Triceratops* and its close relatives, centrosaurines have small horns—which can be pointed, rounded, or modified into bumpy bosses—over their eyes. While the subadult orbital horns of all species are extremely similar, adults can often be readily distinguished. This same pattern—skull features appearing only in adulthood—is perhaps most evident in the frill. Juvenile and subadult centrosaurines have virtually indistinguishable frills; all are relatively thin with simple, scalloped margins. Full-fledged adults, however, possess a variety of hooks, horns, and spikes on the frill, features that are most useful for distinguishing the various species. The evidence strongly suggests that centrosaurine skulls reached adult size before blossoming into their bewildering, and species-specific, array of hooks, horns, spikes, and/or bosses.

Put simply, one of the most important lessons that the bone beds have taught us is: don't judge a horned dinosaur by its youngsters. This lesson has led us to reconsider all centrosaurine dinosaurs. It turns out that the identities of at least a couple of members of this group are based solely on immature specimens. One of these, *Monoclonius*, is a famous ceratopsian that has graced many a children's book, not to mention paleontological journals. All known specimens have rather plain skulls that lack the various "bells and whistles" characteristic of their close relatives. This unadorned look was long considered to be diagnostic of the species, yet animals with large, simple frills and other *Monoclonius*-like features are preserved in virtually all known centrosaurine bone beds. Therefore, the skulls labeled *Monoclonius* most likely represent not a distinct genus and species but a common growth stage for all centrosaurines, and it is difficult to say exactly how these individuals would have looked had they had the opportunity to reach adulthood.

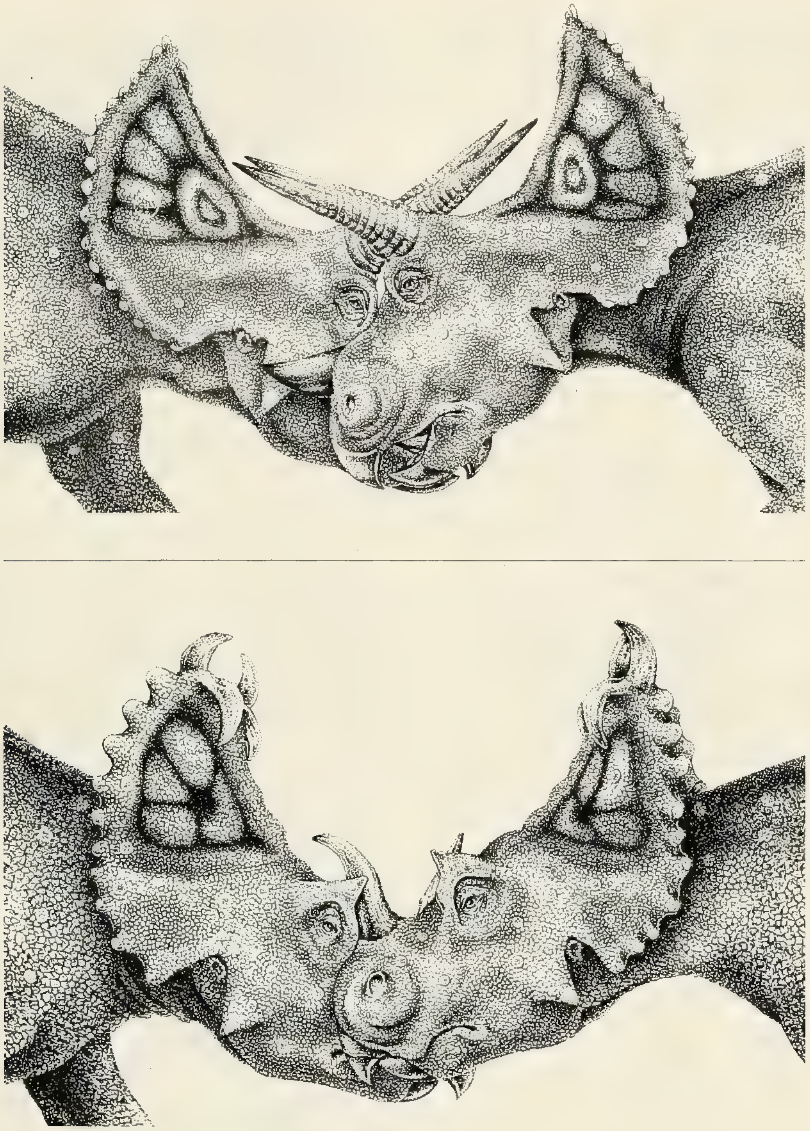
Bone beds have also provided considerable insight into horned dinosaur behavior. Reconstructing the behavior of extinct organisms is invariably a speculative venture, yet certain clues are telling. For example, the abundance of single-species bone beds tells us that some dinosaurs lived in groups at least part of the time. Some paleontologists have speculated that horned dinosaurs and hadrosaurs, or duck-billed dinosaurs—also found in bone beds—migrated great distances in herds on a seasonal basis, much as caribou and wildebeest do today (*see* "Long-distance Dinosaurs," *Natural History*, June 1989).

Horns and frills are variable both within and between species. But what function could these cranial protuberances have served? An oft-depicted clash of the titans involves a *Tyrannosaurus* attacking a *Triceratops*, which is fending off the predator with its horns. While the horns of *Triceratops* and other horned dinosaurs have traditionally been viewed as weapons wielded against predators, I find it difficult to imagine how many horned dinosaurs, including *Einiosaurus* and *Achelousaurus*, could have used their specialized skulls to ward off attacks.

More recent opinion has turned to sex as an explanation for horns and similar appendages. If we look among living animals, cranial outgrowths are used primarily in competition for mates, either as impressive display organs or as weapons for combat against rivals of the same species. This is true not only of mammals such as sheep and buffalo but also of horned animals generally, from chameleons to beetles. Perhaps the specialized headgear of horned dinosaurs and other extinct horned creatures also functioned as secondary sexual characteristics, vital to the animals' success in acquiring mates.

In living animals with marked secondary sexual features, males and females often differ in these outward characteristics, with the males generally being the more ornate sex. We have some evidence that horned dinosaurs were similarly sexually dimorphic. For example, in addition to several forward-curved horn cores, the *Einiosaurus* bone beds produced two short and upright horns that appear to have belonged to fully mature adults. Another bone bed in Alberta has yielded more than fifteen skulls of the boss-headed *Pachyrhinosaurus*. All these specimens have a roughened boss over the nose, but in half of these skulls, the boss is thin and concave, while in the other half, it is thick and convex. Similar patterns have been noted for other horned dinosaurs. Although our samples are still far too small to allow us to draw firm conclusions, one possible interpretation is that gender differences are responsible for these variations.

The growth of horns and frills in mature horned dinosaurs supports the idea that they competed for mates. If horns functioned primarily as antipredator devices, one would expect early, rather than late, development, so they could be put to use as soon as possible. In many living vertebrates, we find delayed or prolonged growth of secondary sexual characteristics. Prolonged growth produces a predictable pattern of visual signals enabling older, larger, fully mature males to mate more often than subadults. These clear and consistent signals permit animals of different ages and strengths to assess one another without resorting to physical conflict. The result is a dominance hierarchy, or pecking order, in which true combat for social position is generally limited to individuals of equal rank. Thus, male bighorn sheep become sexually mature in their



Although their headgear varied, dinosaurs such as Triceratops, *top, and* Centrosaurus, *bottom, may have used their horns and frills for display and nonlethal grappling contests with rivals as they vied for mates.*

Illustrations by Bill Parsons

second year but do not enter the rut and compete for mates until their horns reach a certain minimum size, when they are between the ages of six and eight. As mammalogist Valerius Geist has noted, herd-living animals must be able to determine hierarchical position without life-threatening battles, because herd members depend on one another for survival. More individuals translate into more eyes and ears to detect potential danger, and large, mature males may be particularly important in warding off predators.

Many features common to all ceratopsid skulls and skeletons—horns, an enlarged frill, reinforced orbits and cheek bones, and neck vertebra fused into a strong, bony unit—appear well designed for head-to-head confrontation. The large, paired orbital horns of *Triceratops* and its chasmosaurine kin are ideally suited for engaging in head-to-head wrestling contests, the same kind of grappling modern antelopes undertake. Antelopes and other horned animals have a tough sheath, usually made of keratin, covering the bony horn core. Horned dinosaurs almost certainly had a similar structure and, as in antelopes, the sheath may have been covered by a series of grooves and ridges to aid in holding the horns of an opponent, thereby permitting a nonlethal mode of combat.

Just how centrosaurines, with their relatively small orbital horns, might have carried out similar wrestling matches is hard to envision, but the great variety of horn and frill shapes suggests that several strategies were employed. Species with nasal and orbital bosses, like *Achelousaurus* and *Pachyrhinosaurus,* may have used these structures as platforms to catch the bosses of an opponent, while species with upright nasal horns, like *Centrosaurus,* may have been able to lock their nose horns into the reinforced bony orbits of their rivals (see drawings, left). Even the exaggerated, forward-curved nasal horn of *Einiosaurus* may have been designed to lock against the similarly shaped horn of an adversary.

Viewed as weapons and social signals for mate competition, horns and frills take on increased significance. Prolonged growth of these features points to the possibility that horned dinosaurs lived in complex, hierarchical herds. Moreover, the tremendous variety of horns and frills stands in stark contrast to the evolutionary conservatism of the rest of the skeleton. Jaws, limbs, and other elements associated directly with survival changed relatively little, whereas skull ornamentations, likely associated with mating success, underwent radical changes. This finding suggests that horns and frills may have played an important role not only in the sex lives of the horned dinosaurs but also in their evolution.

According to recent theory, evolutionary modification of secondary sexual features, such as horns, within a species may contribute to the origin of new species. Every animal species has its own particular system by which individual animals recognize and select mates, and many use visual cues. Were these cues to diverge between two populations (resulting, for example, in two horn types) because of mate competition, the groups might no longer recognize each other as the same species, and consequently stop interbreeding. The short- and long-term effects of mate competition are now being investigated in many species of living animals. It is intriguing to consider that sexual behavior may have been a major factor in the remarkable diversity and success of the horned dinosaurs.

True Grit

by David D. Gillette

Excavating the fossil bones was a painstaking and time-consuming task in itself, but the stones slowed our progress considerably. The tail vertebrae, exposed by the weathering of the surrounding sandstone, had led to more bones buried beneath a mesa: the sacrum and hips, part of the vertebral column, including ribs, and several neck bones, all belonging to one enormous dinosaur. The stones were spread unevenly across some 1,600 square feet, but many were in contact with the bones. As the stones were encountered, our team photographed, mapped, and carefully removed each one. Some were the size of a peach pit; most were close to the size of a plum. A few were apple sized and the largest was comparable to a small grapefruit. All were smooth, and they ranged from white to black with a rainbow of colors in between. Early on in the excavation, we found a tight cluster of twenty-six stones in the pelvic region of our skeleton, and as the digging went on, the clustering and patterns of the stones in the quarry became suggestive, something of a lesson in ancient anatomy.

The story started some 150 million years ago, when a giant sauropod died in what are now the arid canyonlands of central New Mexico. Weathered and scavenged, its carcass was eventually reduced to bones, which settled ever deeper into the sand of the ancient riverbed. Its death marked an end to perhaps a full century of life for this prodigious, 50- to 100-ton creature. In 1979, hikers exploring the area for ancient Anasazi rock carvings found, eroding out of the sandstone, eight enormous vertebrae—part of the tail of the eons-dead sauropod.

This chance discovery led to an exciting excavation that took me and my team from the New Mexico Museum of Natural History and the Southwest Paleontology Foundation seven years to complete. The sheer mass and dimensions of the bones were a revelation. One of the ribs was nearly ten feet long, and the sacrum was about five feet high. When the first round of bones, excavated in 1987, was prepared and studied, we realized that this was a new genus and species of sauropod, perhaps the longest and one of the largest of these creatures. (Our original estimates as to length exceeded 110 feet, but by 1991, I projected a realistic snout-to-tail length of roughly 150 feet.) We named our beast *Seismosaurus hallorum,* or "earth shaker"; more casually we just called it Sam. This new genus and species belongs in the family of long-necked, long-tailed sauropods that includes *Diplodocus, Apatosaurus,* and *Barosaurus.*

As our team's excavation of the huge bones progressed, we began to find stones by the dozens, so many that they considerably slowed the pace of the excavation. By 1993, we had documented 240. What were the stones doing near and among the bones? Several stomach stones, or gastroliths, had previously been reported from sauropod excavations in the Morrison Formation in western North America and in the Tendaguru beds of Tanzania. The prevailing theory holds that sauropods swallowed these stones and carried them in a gizzard where the stones helped pulverize the tons of vegetation the huge creatures would have needed to live. When we found the first batch of stones, I

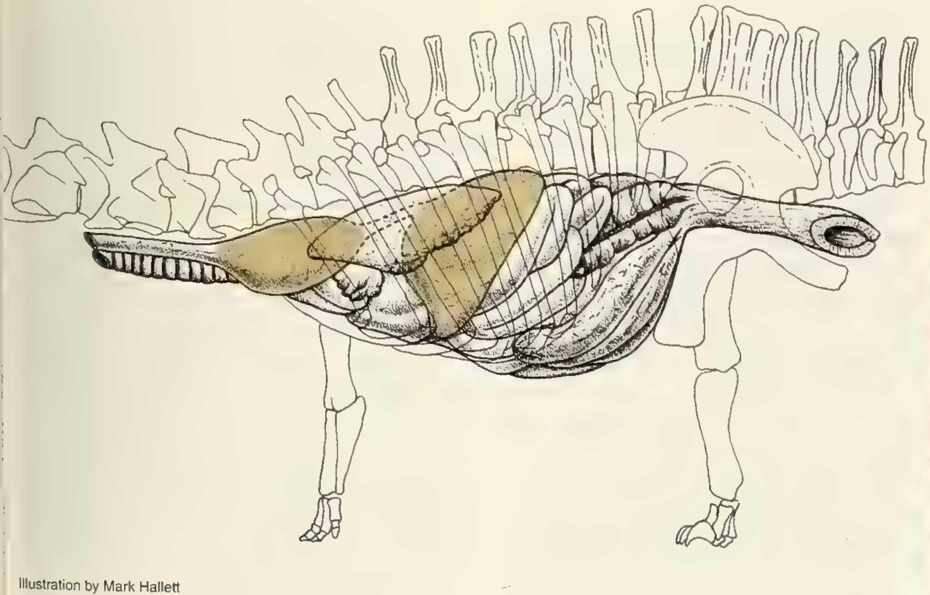
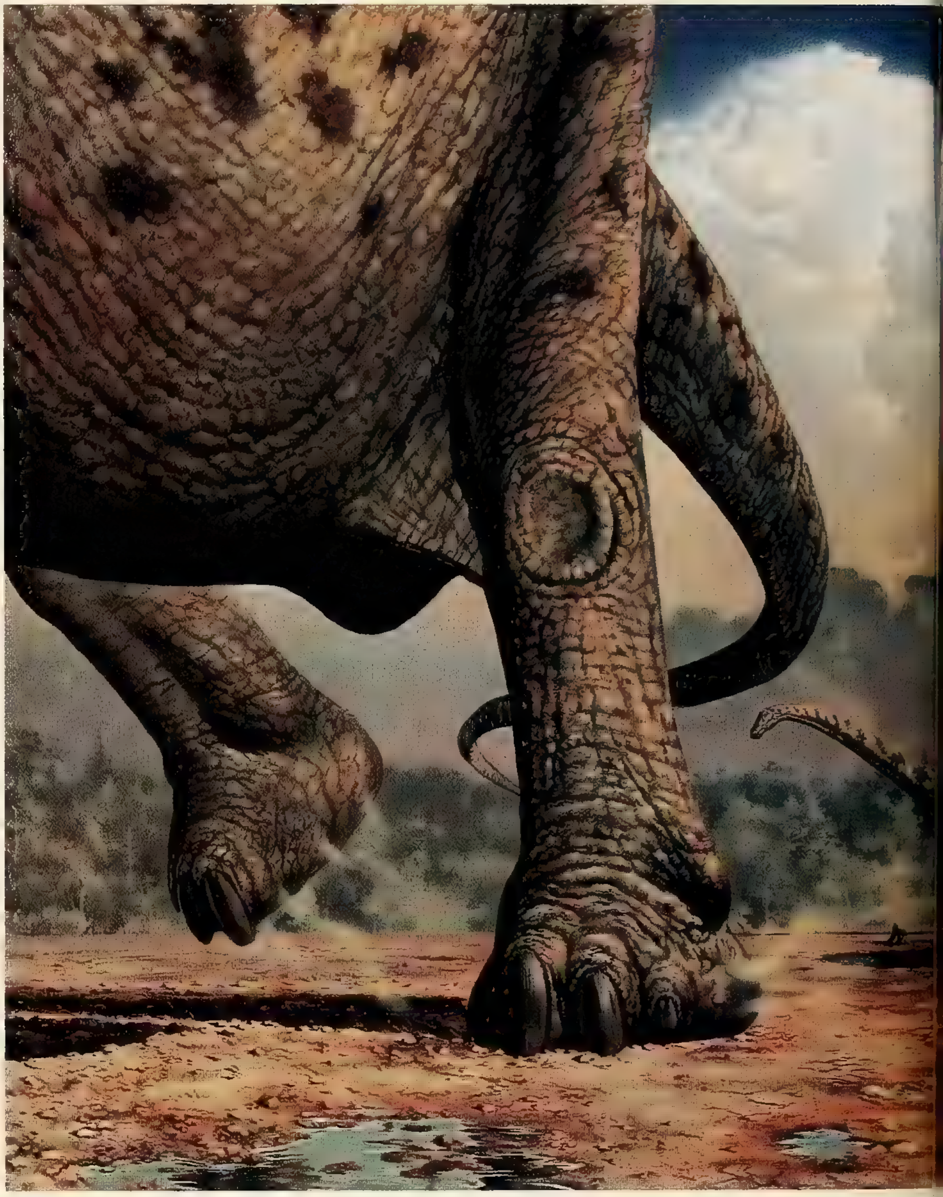


Illustration by Mark Hallett

Stomach stones, or gastroliths, below, were found in two main clusters in association with the Seismosaurus *skeleton, suggesting that the creature's capacious digestive tract included a crop and a gizzard (shaded areas, left).*

David Gillette



Their bodies resembling suspension bridges and serving as a perch for pterosaurs, members of a Seismosaurus *herd move across a mud flat. At an estimated 150 feet,* Seismosaurus *is one of the longest of the sauropods.*
Illustration by Mark Hallett

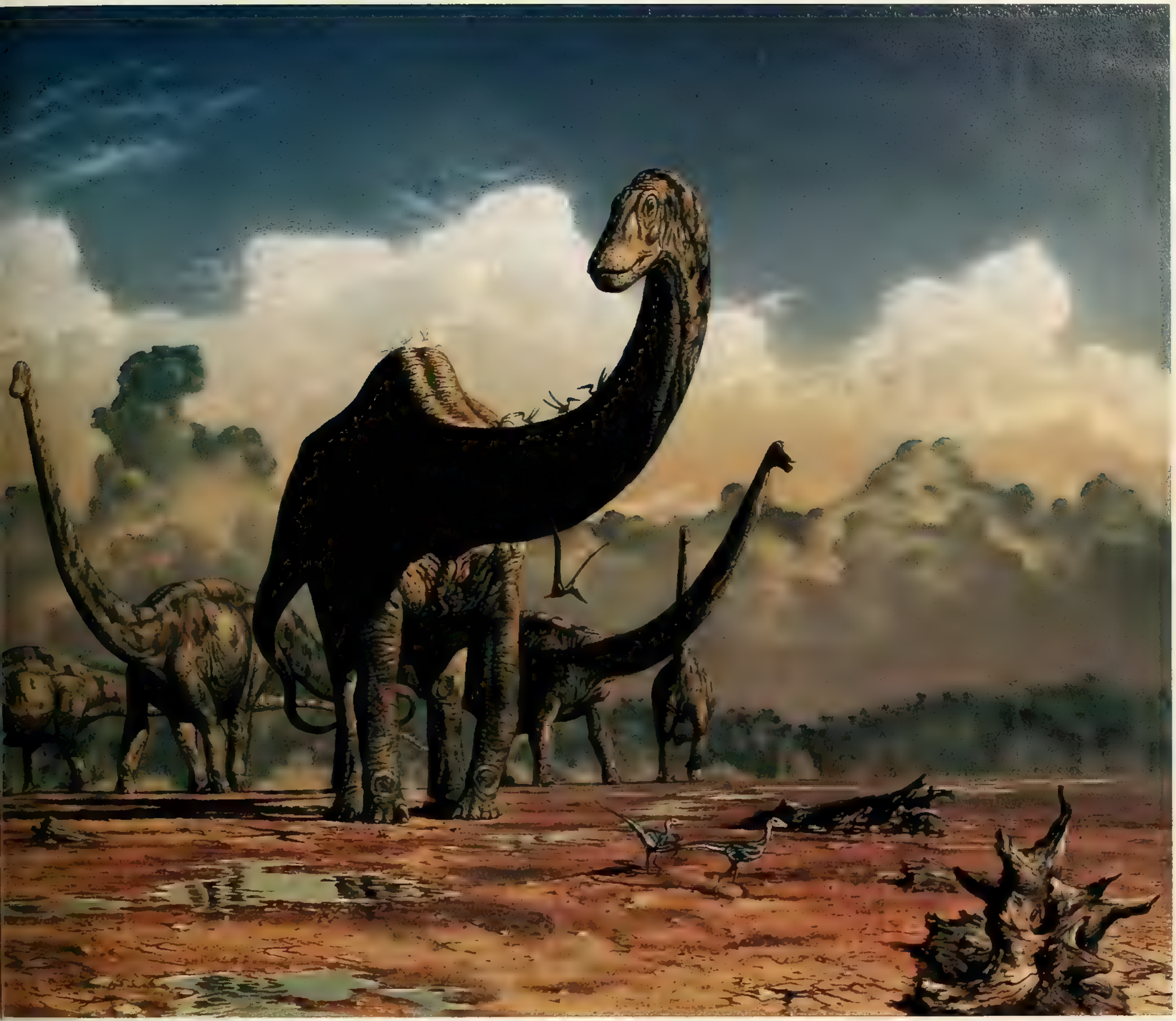
was not convinced that they were genuine gastroliths, although they were situated in a region where a presumed gizzard would have been. I needed to rule out the possibility that they were simply rocks that had been carried by streams and deposited or washed up near the skeleton.

In our quarry, Sam's skeleton lay in the middle of a layer of sandstone twenty feet thick. Except for the presumed gastroliths, no sedimentary materials larger than sand were evident. Ordinarily, stream deposits display gradations in grain size, and they are almost never abrupt. The sands are overlain by increasingly larger or smaller sedimentary materials that reflect a change in stream velocity and carrying capacity. Sam's gastroliths lay directly on sand. In addition, some stones were in direct contact with the ribs and vertebrae and had unusual orientations. One, a flattened disk perfect for skipping across the surface of a pond, was on edge in a vertical position, not a likely attitude for a stream-borne stone. Finally, our stones showed a bell-shaped curve of size, while stream-carried stones would show a more linear decrease in size, with a few large ones, more of intermediate size, and many small ones.

We concluded that these stones were indeed gastroliths contained in Sam's stomach at the time of death. In contrast to all other reports of gastroliths, these are the first to be documented in direct association with the skeleton. Their positions in the quarry therefore offer clues to Sam's anatomy, and more generally, to sauropod anatomy.

All the gastroliths are exceptionally rounded, and some, but not all, are so thoroughly polished that they are waxy. They are composed of quartz and its many varieties, such as jasper and quartzite, the hardest and most durable of the naturally occurring and abundant minerals. Such stones, available in almost any streambed during the Jurassic, could easily have been swallowed by a sauropod. Sam probably selected rounded river stones to ingest. Subsequent rolling action of the stones in the alimentary canal smoothed sharp edges as the stones ground against one another. The origin of the polish is more problematical. The grinding action that rounded the stones would also leave them slightly roughened; I believe that rather than being polished by grinding, some of the stomach stones were isolated in folds or pockets of the digestive tract and were rolled and buffed by the soft, pliable tissues that held them in place, like a shoe being polished with a soft cloth. The action of digestive juices and enzymes may have enhanced the polishing action, imparting to some of the stones their spectacular luster. I also surmise that the stones in the digestive tract for the longest time would be more polished than newer ones. Perhaps gastroliths remained in the tract for years, or until they were almost totally ground down, say to the size of peach pits, and passed through the digestive tract along with food.

In addition to the first tight cluster of stones in Sam's pelvic region, which could be attributed to the gizzard, we found another, more scattered group of stones. This set—spread out and accounting for the majority of stones—seemed to be centered at the front part of the chest cavity, near the base of the neck. Between the two sets was an empty stretch of at least four feet. This apparent separation is evidence of a specialized forward chamber in Sam's digestive tract, which I have called a crop because its position would have been similar to the position of the crop in grain-eat-



ing birds such as chickens. (These birds are also known to swallow grit.) All the gastroliths from this region are as highly polished and rounded as those from the gizzard and are much more numerous, indicating that the front gastroliths were also involved in processing food. This is not the case in most birds, whose crop functions as a storage chamber. Only one bird, the hoatzin of northern South America, has a crop with a gizzard's function—not proof of a crop in sauropods, but evidence that a food-processing crop is possible.

Overall, we have reasonable evidence to propose that Sam's digestive system resembled that of grain-feeding birds: esophagus, crop, stomach, gizzard, and intestine. But just how did sauropods use the gastroliths in digestion? One theory holds that because sauropods had relatively small, weak teeth, yet needed vast amounts of food, stomach stones were necessary to sufficiently grind vegetation. I disagree. Not all sauropods had gastroliths, and while we found many in association with Sam, given Sam's capacious digestive system (some of the largest ribs surrounding the digestive tract are approximately nine feet long), the volume of stones was small, only about ten quarts. I do not believe that they were used as a substitute for teeth, but instead were optional or supplemental to digestion. Some individuals used gastroliths, others did not. Their use was neither obligatory nor accidental.

I propose that rather than functioning as grinding stones, gastroliths served as a digestive aid by stirring digestive juices, much like a magnetic stirrer in a chemistry laboratory. A small stirring device can create sufficient turbulence to circulate fluids throughout a beaker, preventing unwanted settling and segregation of materials by density. Gastroliths could have helped to keep foodstuffs and the digestive juices mixed. I subscribe to this notion particularly for the crop, which was probably distensible and not highly muscular. After being prepared in the crop, food underwent more vigorous chemical treatment farther along in the tract and perhaps some grinding in the gizzard.

During its long life span, Sam was sustained by prodigious meals of ferns, cycads, and conifers. To help process the tons of Jurassic fare it needed to survive, the enormous sauropod may well have relied on the occasional digestive aid of gastroliths, dinosaur true grit.

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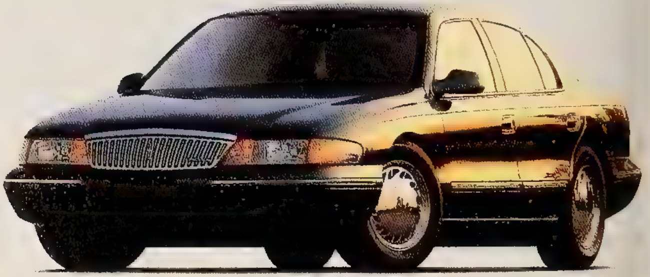

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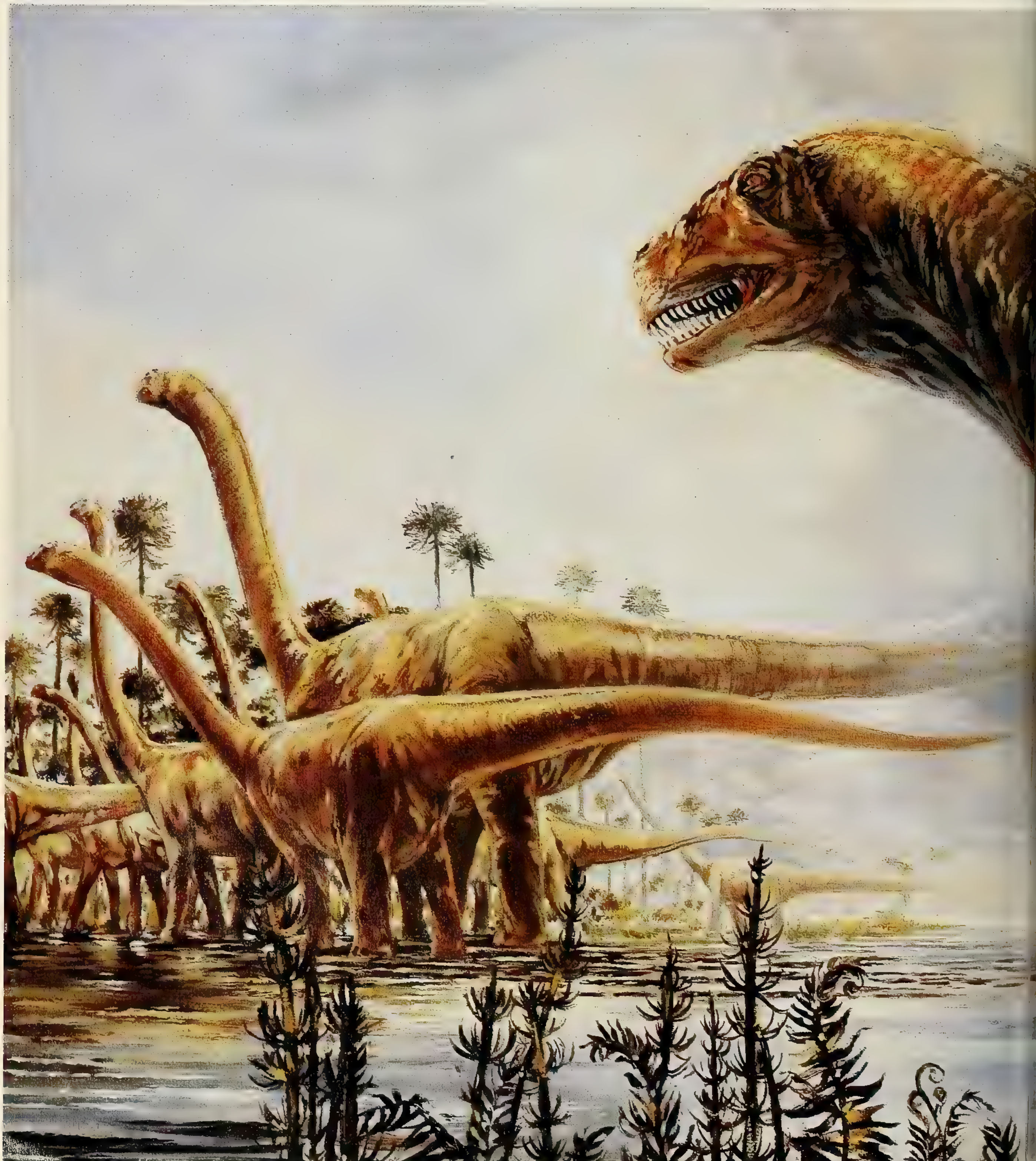
What A Luxury Car Should Be

Track Records

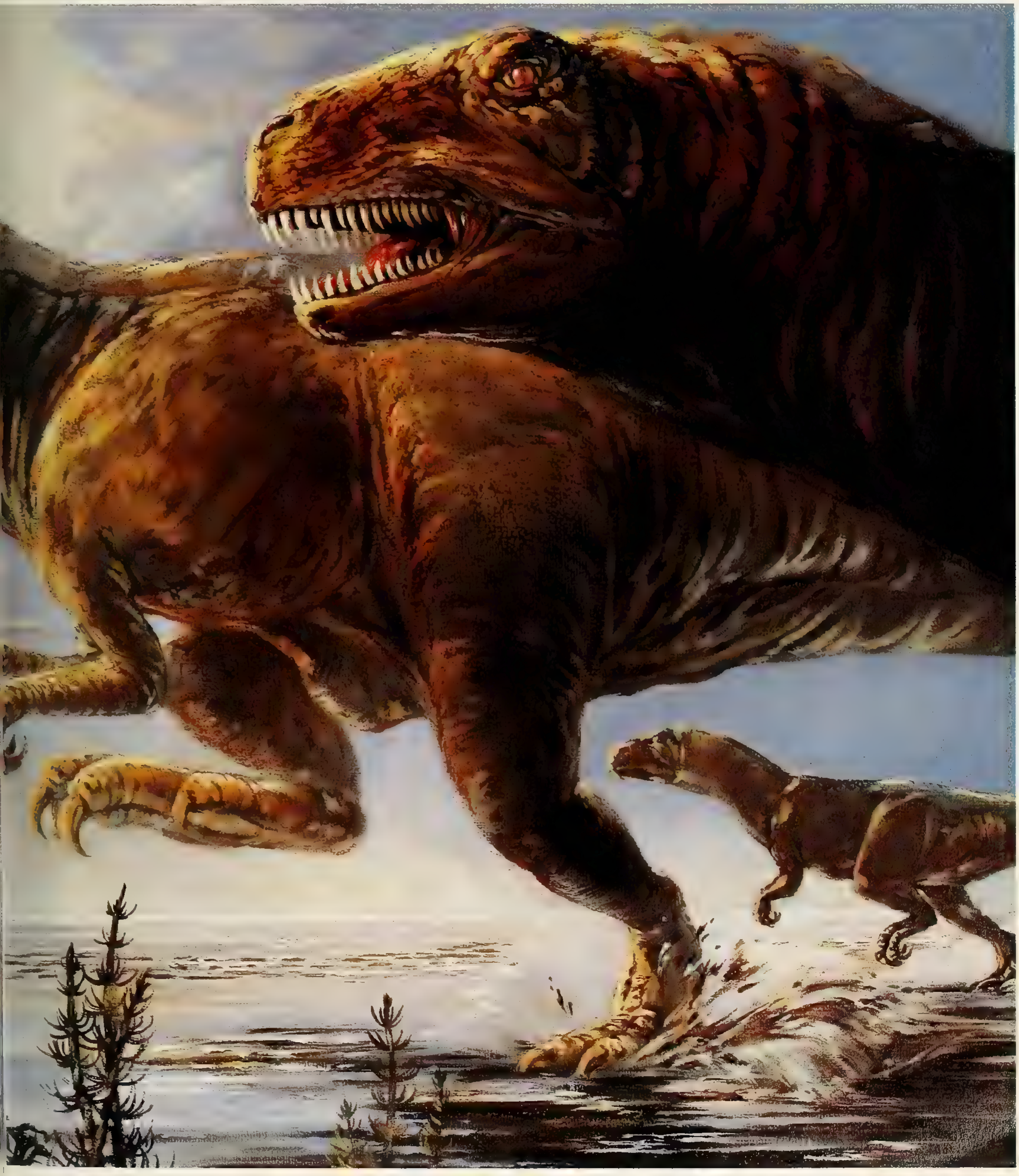
by Martin Lockley

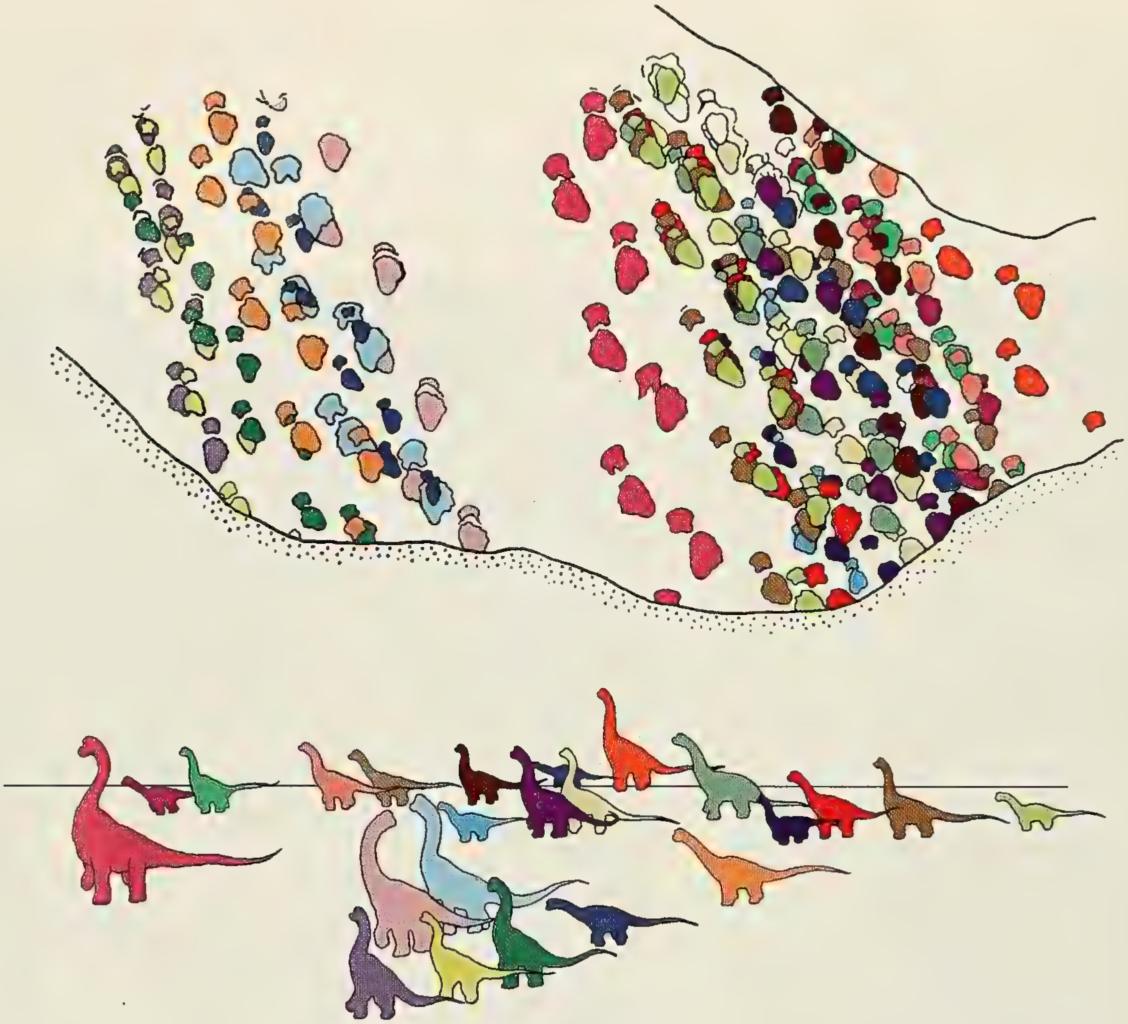


The past decade has seen a resurgence in the search for, and study of, fossil footprints, those seemingly ephemeral traces in the sands and muds of time. While time and erosion have indeed obliterated more than 99 percent of tracks, a surprising abundance of footprints of dinosaurs and their contemporaries—birds, mammals, amphibians, and pterosaurs and other reptiles—were set in stone. Tracks are especially numerous in comparison with bones. This is not only because each animal could make millions of tracks in a lifetime; it is also a function of where and how tracks are made and preserved. Unlike bones, which usually end up on the

A herd of sauropods ambles along a mud flat, with three alert predators in its wake. Were the carnivores stalking the herd, eager to pick off young or stragglers? This reconstruction is based on the Glen Rose, Texas, trackway, which has given rise to various theories of possible predation in progress.

Illustration by Karen Carr





Measurement and color coding of the tracks at Davenport Ranch in Texas reveal that twenty-three sauropods crossed the area together. Track sequences and their extensive overlapping suggest that most of the animals were moving in line, with the largest individuals leading the herd.

Illustration by Martin Lockley

surface after an animal dies and have to be washed into a site with particular conditions if they are to be preserved, tracks are the result of an animal constantly sticking its feet into the mud, sand, and other impressionable surfaces that form the very foundation of sedimentary rocks today. Dinosaurs and other ancient creatures were extremely obliging in making direct impressions into what is now the fossil track record.

What, then, can be learned from such a vast storehouse of footprint data? Tracks (or footprints) and trackways (trails of consecutive tracks) are dynamic evidence of creatures on the move. As paleontologist Greg Paul put it, they are the nearest thing we have to movies of living dinosaurs. Trackways thus provide insight into a wide range of individual and social behaviors. For example, they can be used to estimate speed; trackways suggest that a few medium-sized theropods—bipedal carnivorous dinosaurs—occasionally ran as fast as Olympic sprint champions. Large quadrupedal dinosaurs such as the huge sauropods, plated stegosaurs, and armored ankylosaurs may have been able to run, but according to the track record, they ambled most of the time.

Although most trackways record dinosaurs that were simply walking, not all exhibit monotonously regular patterns. Every so often we find a trackway in which alternating long and short steps testify to animals that had a distinct limp. The reasons for such abnormalities are generally not known, although we do know that the afflicted individuals range from sauropods to theropods to ornithopods (duck-billed hadrosaurs and their kin). In one case, a limping theropod left tracks showing a distinct foot deformity.

Analyses of sauropod trackways show that they fall into "wide gauge" and "narrow gauge" categories, as noted by paleontologist James Farlow. This observation may be the first step toward using tracks to distinguish between sauropod families. Brachiosaurs, for example, were probably wide gauge and are indeed wide bodied in comparison with members of other families of sauropods that must have produced narrower trackways. My research group and I conducted a follow-up analysis of more than 400 sauropod trackways from around the world, which usually indicated only one category on any given surface. In addition, narrow-gauge forms are more common in the Jurassic, from about 208 to 145 million years ago, whereas wide-gauge forms predominate in the Cretaceous, from 145 to 65 million years ago. This suggests that as sauropods evolved over time, their locomotor style changed.

Single surfaces with abundant trackways of the same type are common, and a significant number of these sites, especially those with footprints of sauropods and ornithopods, display multiple, parallel trackways. Not every example of two or more parallel trackways is convincing evidence that the animals preferred to live in groups, since such patterns may result from individuals following a preferred path, such as a shoreline or riverbank, over long periods of time. But when we find dozens of parallel trackways that are of the same type and are also regularly spaced and of the same depth, the evidence for the passage of a herd is compelling.

In the late 1930s, Roland T. Bird, the longtime field assistant to fossil-hunter Barnum Brown of the American Museum, was the first to report convincing dinosaur trackway evidence for social behavior, long before other lines of evidence, such as the existence of nesting colonies, emerged. Following leads that took him to outcrops of 100-million-year-old limestone in Texas, Bird discovered two small but significant sites. The first, now the site of Dinosaur Valley State Park, near Glen Rose, Texas, was the scene of a major excavation to remove a segment of sauropod trackway and a parallel segment of theropod trackway, which are on display in the American Museum's new Hall of Saurischian Dinosaurs. Although these have been cited as evidence for a predator (the theropod) attacking its prey, I have serious doubts about this interpretation. Based on Bird's map and original field observations, the site contained twelve regularly spaced, parallel trackways of large sauropods and trackways of not one but three large theropods following the same path. Rather than a one-on-one attack, I believe that these trackways represent a group of theropods stalking or following a herd of sauropods.

Bird's second site, known as Davenport Ranch, contains twenty-three trackways of sauropods of different sizes. All but two of the trackways of larger animals overlap, indicating that the sauropods were crossing the area in a line, not spread out on a broad front. The suggestion has been made that the large animals were protecting their young in the center of the herd. I have carefully analyzed Bird's meticulous map and have color coded and measured each trackway (see opposite page), paying special attention to what overlap could reveal about the sequencing of prints. Although the image of protective parents is an appealing one, the evidence is lacking. However, we can conclude that the herd veered from right to left and took a minimum of several minutes to cross the area, and that some of the larger sauropods were leading the way.

Since Bird's day, further examples of parallel sauropod trackways have been discovered, including other 100-million-year-old Cretaceous sites in Texas and 150-million-year-old late Jurassic sites in Utah, Colorado, and Portugal. The trackway evidence for social behavior in sauropods is thus widespread, and we can begin to look for patterns. Both wide- and narrow-gauge sauropods appear to have traveled in groups. Some were composed only of large animals, others only of small animals, and occasionally we find a mixture of sizes. I suspect that sauropods were social throughout their long history, from their first appearance in the Jurassic to their disappearance at the end of the Cretaceous, not just for the two epochs for which a good track record exists.

In contrast to the wealth of clues to sauropod sociality, only three tracksites, in Connecticut, Bolivia, and Australia, have been reported as examples of gregarious behavior in the carnivorous theropods, even though theropod trackways are abundant. Perhaps these predators were less social than their plant-eating contemporaries. For some of the other large

Lasting Impressions

Tracks are often regarded as short-lived phenomena, easily destroyed by the next tide or flood to wash over them. Indeed, our studies of modern tracks at Lake Manyara in Tanzania confirm that they remain in recognizable form at the surface for only a week or so before being obliterated by rain, waves, or trampling by other animals. This has led to the notion that tracks can only be preserved if they are made in suitable settings where the exposed clay or sand is rapidly dried by sun or wind so that it becomes rock hard by the time the next tide or flood washes in an overlying layer of sediment. But this explains only one way in which tracks are preserved.

Another explanation has been overlooked until recently: large animals make large footprints that can penetrate deeply into sedimentary layers and register on surfaces that are already buried. Such buried tracks may record where the actual foot came to rest, or they may represent "undertracks" on a surface just below the deepest level at which the foot came to rest. In either case, the footprints are safely buried beneath the surface and thus are protected from the destructive forces of erosion and weathering. At Dinosaur State Park, in Connecticut, visitors can see a fine example of the trackway of a prosauropod (one of a group of large quadrupedal dinosaurs that resembled, but preceded, the sauropods). Each footprint in the trackway is so detailed that beautiful skin impressions are visible. In between each of these tracks, the sediment surface was scoured by the erosive force of sand-laden flood waters that covered the surface after the tracks were made. But the indented tracks were nestled in the substrate as localized and protected pockets, and thus escaped damage from the erosion.

In more than a decade of tracking, I have found a track of a baby carnivorous dinosaur in Utah that was less than two inches from heel to toe tip and the footprint of a sauropod in Colorado that was close to a yard in diameter and two feet deep. Track depth, however, is a measure not of the weight of the track maker but of the water content and consistency of the sediment. (A 130-pound person makes deeper tracks in mud than in firm sand.) The weight of the track maker can be estimated, however, from the size of the tracks. Various formulas show that most dinosaurs have a hip height four or five times their foot length. We can then extrapolate from foot size to leg length, then to overall body size, and finally to estimated weight.—*M. L.*

Track Sampler

Where can one go to see tracks? Many are on view on public lands and in museums. A few of the most notable follow.

Dinosaur Ridge, designated a National Landmark, is near the town of Morrison, Colorado, to the west of Denver. A trail allows visitors to stroll along Cretaceous trackbeds that form part of the western "dinosaur freeway."

Dinosaur Valley State Park in Glen Rose, southwest of Fort Worth, is the most famous tracksite in Texas. Although the actual trackways are often inundated by the waters of the Paluxy River, the site is rich in trackway history. Here, sauropod trackways discovered by Roland T. Bird provided the first evidence of herding in sauropods and gave rise to conflicting theories about whether carnivorous dinosaurs had been stalking the herd. Part of the original trackway was excavated and is on view in the Hall of Saurischian Dinosaurs in the **American Museum of Natural History** in New York.

Dinosaur State Park, in Rocky Hill, Connecticut, just south of Hartford, offers an outdoor area in which visitors can make plaster casts of tracks. The park contains many *Eubrontes* tracks, attributed to a Jurassic theropod, and features "on-site" preservation. Five hundred tracks, in their original positions, are housed in an interpretative building. (Renovations to the building will be completed in fall 1995.)

herbivores also, trackways are still scarce. We have no tracksites showing social behavior among either stegosaurs or ankylosaurs, and only one site suggests that the horned dinosaurs were social, but this is probably because tracks of all three groups are, so far, rare. In contrast, ornithopods, especially the large Cretaceous iguanodonts and duckbills, left an extensive track record of social activity.

Dozens of ornithopod trackways in Colorado, New Mexico, Utah, Canada, England, and Korea suggest that these animals lived in herds. At the New Mexico site, our research team and other trackers have mapped fifty-five parallel trackways of small individuals all heading north and trackways of twenty-five larger individuals heading south. (One of the smaller animals was limping but apparently kept up with the herd.) The pattern of large individuals going one way and small ones another is repeated at sites in Colorado and is reminiscent of the segregation of animals by size at most sauropod tracksites. These dinosaurs seem to have enjoyed the company of individuals of their own species that were of the same size and, presumably, the same age. Size groupings could also represent male and female congregations, but this is mere guesswork.

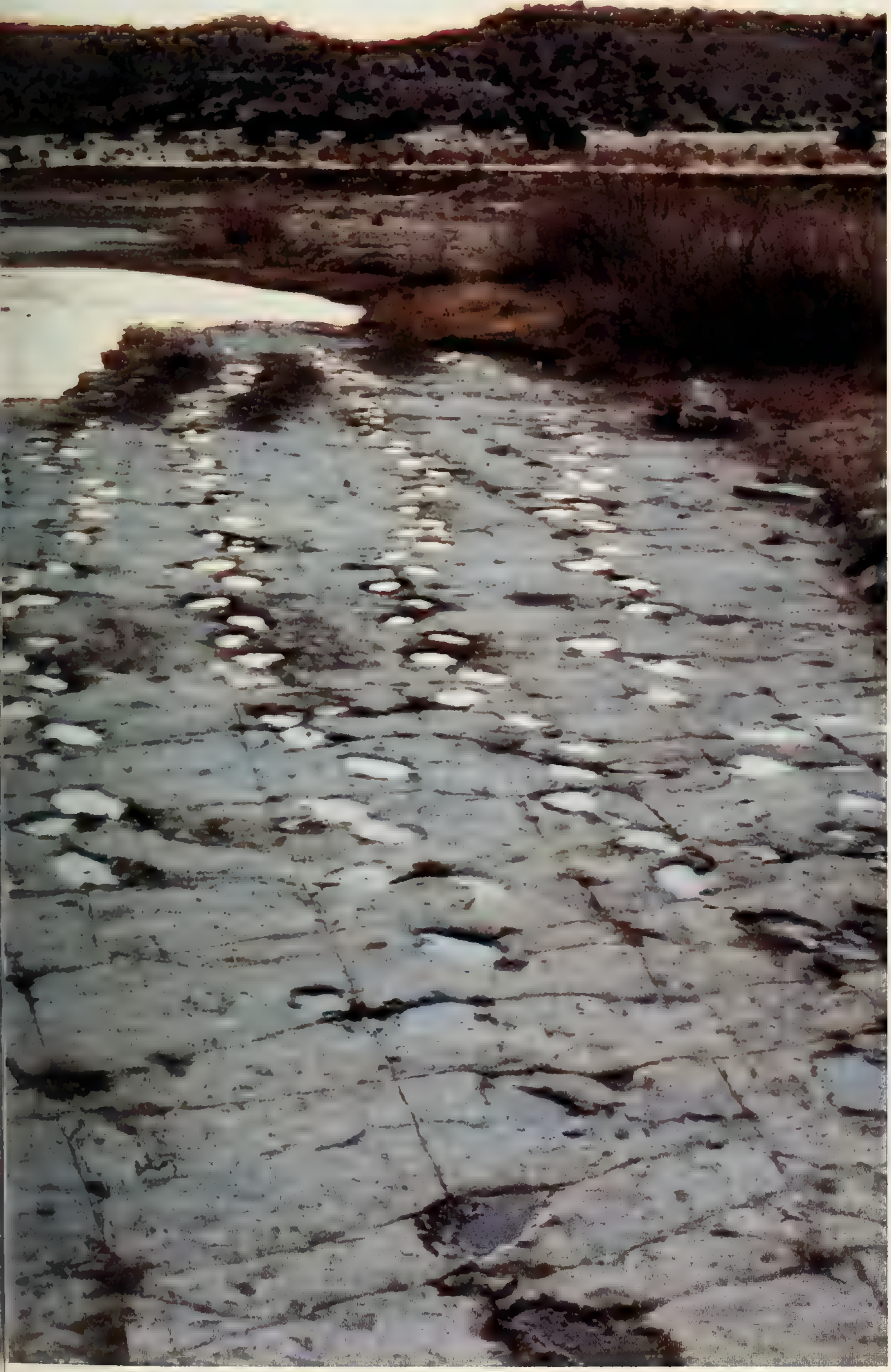
The visible track-bearing surface of rocks is usually controlled by the erosion of sedimentary layers in cliffs, quarries, streambeds, and wherever the rocks are exposed. When a trackway abruptly disappears, every tracker knows that there must be more tracks in there, where the layer is still buried. But how can one tell how far the layer goes before one runs out of tracks on the original surface? The only way is to follow the layers as best we can wherever they surface. Although this is impossible in some cases, in others it can lead to spectacular results.

By piecing together information from every available outcrop, we have now traced several surfaces over huge areas. We call these megatracksites. The oldest and smallest (a few hundred square miles) are in 150-million-year-old rocks in Utah and Switzerland; the largest—on the order of tens of thousands of square miles—are three sites about 100 million years old in the western United States. Such extensive trampled layers conjure up images of huge numbers of dinosaurs stomping around, and certainly such an image is consistent with the evidence of widespread herding. Megatracksites also reflect ancient geology; they represent once-extensive coastal plain deposits, similar to the present-day coast of the Gulf of Mexico, in which large stretches of land lie close to sea level. In such settings, mud flats, marshes, swamps, delta plains, and other wetlands provided ideal surfaces for track making.

Two of the western U. S. megatracksites are in Texas and incorporate Bird's famous sites and about fifty others into vast limestone complexes that represent the Gulf Coast plain of 100 million years ago. About two million years later, the sea penetrated North America to form the great Western Interior Seaway, whose shores ran north–south through parts of Colorado, New Mexico, and Oklahoma. Dinosaurs moving along these shores left trackways that today run roughly parallel to an interstate freeway. Taken together, these trackways form another megatracksite, dubbed the "dinosaur freeway."

Each of these megatracksites reveals individual sites where we have recorded one to ten tracks per square yard (one to

twenty-five million per square mile), leading to an estimate of literally billions of prints for each megatracksite. Given these astronomical numbers, the track record is remarkably consistent. Almost all the Texas sites are those of sauropods and large theropods in limestone, whereas the interior dinosaur freeway records only large ornithopod and small theropod tracks, along with crocodile and bird tracks, in sandstones and mudstones. Thus, each megatracksite has its own distinctive faunal record relating to particular ancient environments. Such consistency throughout each complex is a fine advertisement for the fidelity of the track record in revealing the representative composition of dinosaur communities and even the population structure at any given time. The abundance of tracks also highlights the sparse nature of the skeletal record, for not a single bone is known from the dinosaur freeway area, and precious few are known from Texas.



The consistent track censuses obtained from the dinosaur freeway have led to suggestions that it was a dinosaur migration route, and indeed it may have been. Iguanodont and hadrosaur track makers appear to have ranged over an area of about 30,000 square miles. As large herbivores that were both abundant and gregarious, they probably migrated to avoid depleting resources in a particular area. The megatracksite does not prove unequivocally that individuals or herds migrated along particular routes, but it does show the scope of their movements and is about as near to direct evidence of migrations as we are ever likely to extract from the fossil record.

A decade ago, we knew only of Bird's discovery of two sets of parallel trackways from Texas. Today, we have abundant trackway evidence for social behavior among a variety of sauropods and ornithopods from around the world. In addition, we have at least some indication of social behavior among theropods and horned dinosaurs, a theory that is further supported by discoveries of nest sites and bone beds (*see* "Horns, Herds, and Hierarchies," page 36). Thus, the growing trackway database indicates that most of the major dinosaur groups engaged in social behavior at least part of the time. Trackways can also tell us where, when, and how many animals were active in a particular area, to what groups they belonged, in which direction and how fast they traveled, the size range of individuals in a given sample, whether any social tendencies were common or persistent in a particular group, and when in geological time they first appeared.

Just as important is the great promise dinosaur tracking holds for giving us a greater understanding of the distribution of dinosaurs, and other extinct creatures, in both time and space. In particular, sites with multiple trackways can provide censuses of ancient animal populations and communities. The renaissance in fossil-footprint research during the past ten years has made these "moving pictures" of dinosaurs a mainstay of paleontology.

When rain falls on the Jurassic-age rocks of Purgatoire Valley, Colorado, the parallel tracks of five sauropods become small reflecting pools.

Martin Lockley

A Diversity of Early Birds

by Luis M. Chiappe

On a walk through New York's Central Park, even the casual stroller can observe the diversity of bird life. Mallards dabble and herons hunt in the lake, gulls and an occasional red-tailed hawk soar overhead, and songbirds and woodpeckers forage among the trees. Although varied—some 10,000 extant species are known today—these birds represent just one branch of the avian family tree. Tens of millions of years ago during the Mesozoic, the geological age when large dinosaurs ruled the earth, birds of many different feathers thrived. Their remarkable diversity is just beginning to come to light.

The known history of birds began some 150 million years ago, when a pigeon-sized "feathered dinosaur" perished and sank into the salty waters of a coral reef in what is now southern Germany. *Archaeopteryx,* as it came to be known, was first reported in 1861 on the basis of a skeleton found one year earlier in the limestone quarries of Solnhofen. Another *Archaeopteryx* skeleton had been found six years earlier but remained misidentified as *Pterodactylus*—a flying reptile, not a feathered dinosaur, or bird—until 1970.

The discovery of *Archaeopteryx* in the 1860s played an important role in the newly emerging theory of evolution by natural selection. In the eyes of Darwin's defenders, *Archaeopteryx* represented a transitional form between two major groups of vertebrates—a missing link that combined avian wings and feathers with typical reptilian features such as teeth, sharp claws in the wings, and a long, bony tail. Today, *Archaeopteryx* remains vital to studies dealing with such challenging evolutionary problems as the origin of birds and the development of flight, although 130 years of research have not removed some controversies about its biology. While some researchers view *Archaeopteryx* as arboreal, several lines of evidence indicate that this ancient bird was a swift bipedal runner with limited flying ability.

Just a few years after the discovery of *Archaeopteryx,* field parties organized by the renowned nineteenth-century fossil hunter Charles Othniel Marsh found numerous bird remains in rocks formed 90 to 75 million years ago at the bottom of a shallow sea that ran south–north through North America. These birds, now known as hesperornithiforms and ichthyornithiforms, have subsequently been found in similar deposits in the Old World.

Mid- to large-sized birds, the hesperornithiforms (a group that includes *Hesperornis* and its kin) had a long, pointy, toothed skull and jaw, diminutive forelimbs, and stout hind limbs. Their heavy-boned bodies were covered with small, hairlike feathers. Like present-day loons and grebes, hesperornithiforms were highly efficient divers, and their feet were probably lobed—like those of grebes—and specialized for underwater propulsion. These flightless birds spent most of their lives in the water, plunging after and capturing fish, and only occasionally ventured onto shore. Most hesperornithiforms inhabited marine waters, although in recent years they have also been found in rocks formed in ancient freshwater environments.

Their contemporaries, the tern-sized, big-headed ichthyornithiforms, such as *Ichthyornis,* had a much different lifestyle. They were active fliers that inhabited the shores of ancient seas and shared the sky with large pterodactyls such as *Pteranodon.* They often flew far offshore to feed, perhaps plucking fish from the surface like gulls or terns. Unlike present-day birds, ichthyornithiforms had teeth to help them catch and dispatch prey.

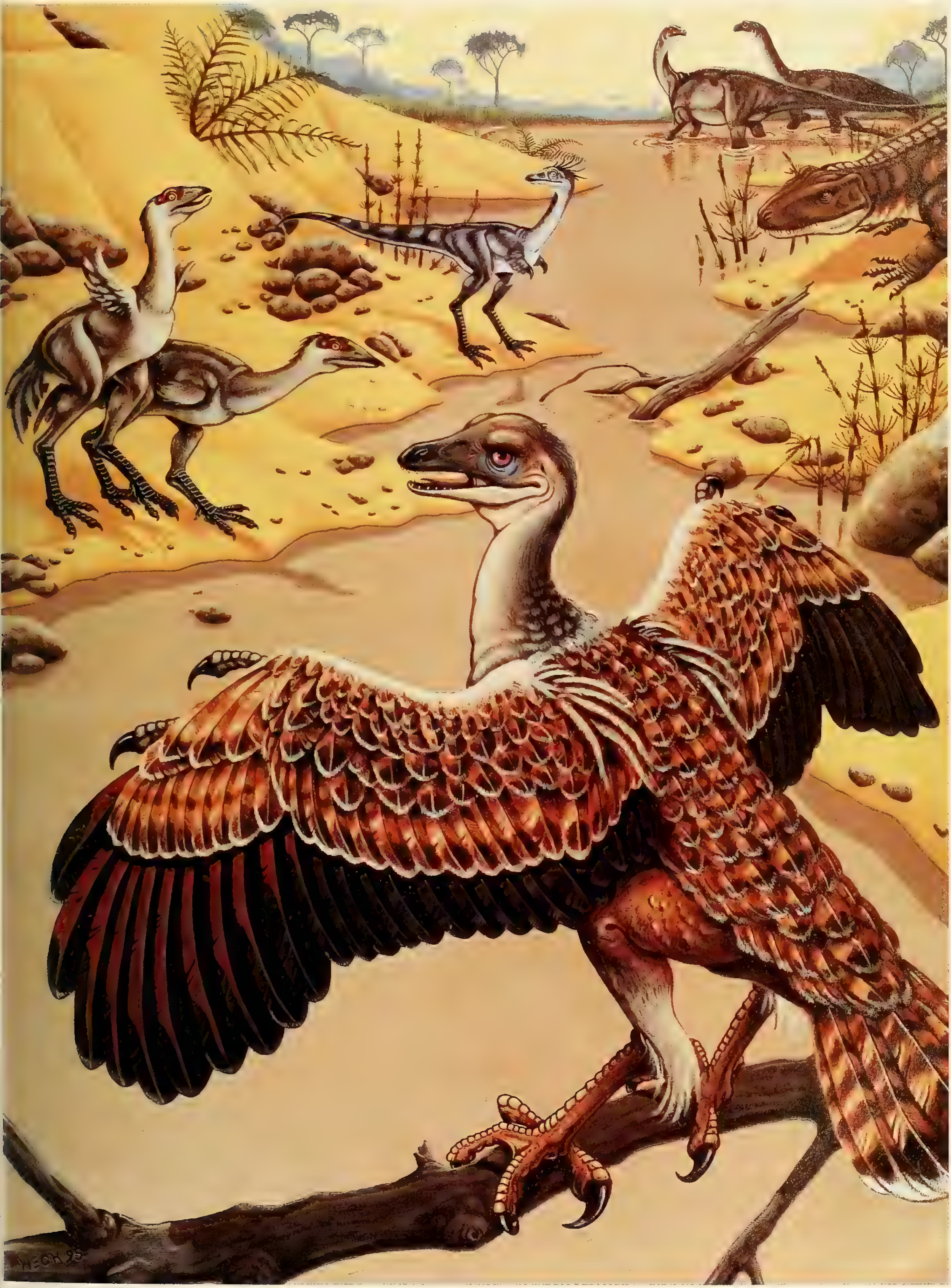
Pioneering discoveries of *Archaeopteryx,* hesperornithiforms, and ichthyornithiforms in the 1800s only hinted at the diversity of primitive birds. More recently, paleontological field research has started to produce a fuller picture of the varied avian world during the age of dinosaurs. During the last fifteen years alone, more members of the bird family have been unearthed than during the entire previous century.

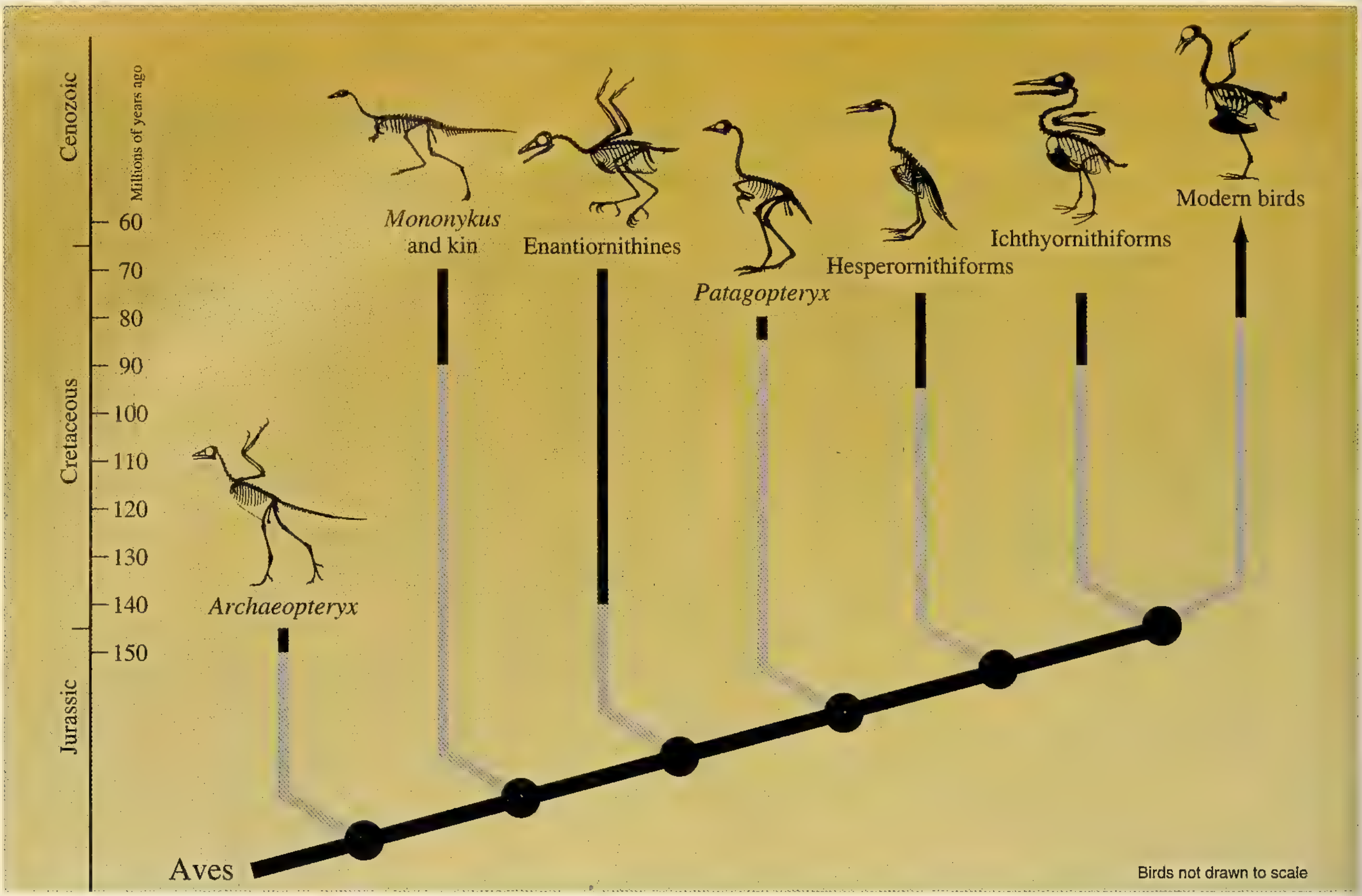
In the mid-1970s, while prospecting 70-million-year-old rocks in northwestern Argentina, a member of the Universidad de Tucumán's field party, who had gotten lost in the misty, dense forests of the region known as El Brete, discovered a series of dinosaur bones sticking out of a hill. During the excavation that followed, the team found a variety of small bird bones jumbled together with those of their giant relatives. This fortuitous finding gave us our first glimpse of the great diversity of Mesozoic birds. Fossils of enantiornithines—the scientific name given to the birds first discovered at El Brete—have now been found all over the world in rocks ranging from 140 million to 70 million years old. Some of the specimens, particularly those recently found in Spain and China, are among the finest fossils of ancient birds.

The enantiornithines were flying birds and varied greatly in size; some, like the Chinese *Sinornis,* were as small as a sparrow, while the Argentine *Enantiornis* was as big as a turkey vulture, with a wingspan of about four feet. Some were long legged and lived along the shore, while others

Birds flourished 85 million years ago. The falcon-sized Neuquenornis *perches and stretches its wings, while a pair of flightless* Patagopteryx *and a blunt-clawed relative of* Mononykus *preen at the water's edge. The crocodile* Notosuchus *eyes the birds, and two sauropods approach to drink on the opposite bank.*

Illustration by Ed Heck





The fossil record (vertical black lines) reveals that living birds (far right) are just one branch on the rich and varied avian family tree.

Illustrations by Ed Heck

were more aquatic. The most common, however, were small to medium sized and most likely lived in trees, for they had feet specialized for perching and grasping.

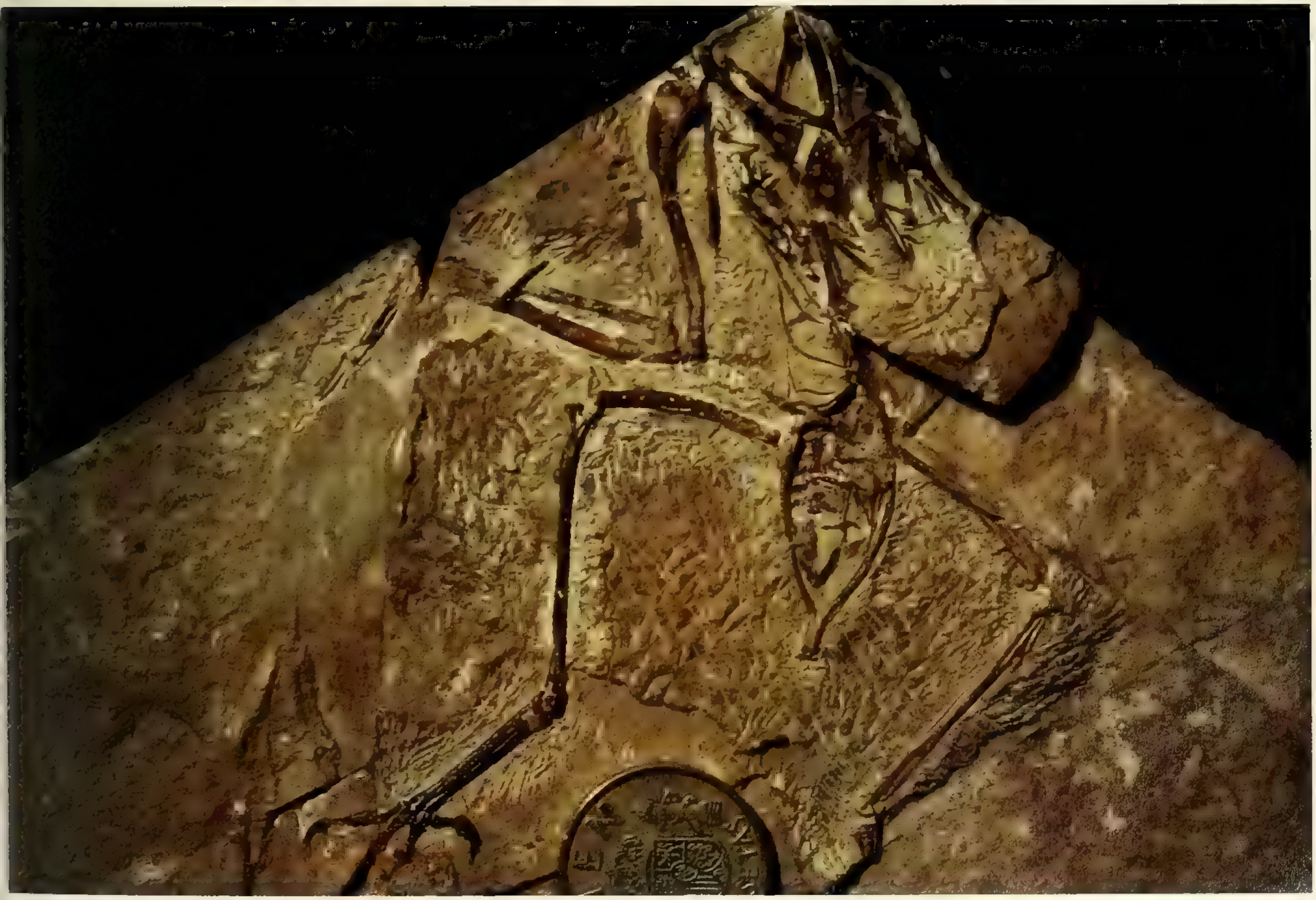
Like many birds today, some enantiornithines laid eggs on the ground. Numerous ground nests—some including eggs with embryos—have been found entombed in eighty-million-year-old rocks in Mongolia. Anatomically, however, the enantiornithines differed from modern birds in many respects, having clawed wings and, in earlier forms, toothed jaws. Perhaps the most striking difference between these ancient birds and their living counterparts was revealed by microscopic examination of cross sections of their limb bones. Paleontologists Anusuya Chinsamy, Peter Dodson, and I conducted these studies, using thin slices of leg bones from two specimens from El Brete. The sections showed a pattern of growth rings, like those formed in trees during annual wet and dry seasons. Enantiornithines, then, underwent annual cycles of growing periods and pauses. These patterns, along with the virtual absence of blood vessels in the bones, indicate that unlike their remote living relatives, the enantiornithines were not fully warmblooded, as we use the term for living birds and mammals. This conclusion, however, does not necessarily mean that they were coldblooded. The bone microstructure of nonavian carnivorous dinosaurs, such as *Syntarsus* and *Troodon,* indicates that these creatures were metabolically more active than, for example, a lizard. But we do not yet have enough evidence to conclude that they were as active as modern birds. I believe that primitive birds such as the enantiornithines and their dinosaurian ancestors had a kind of metabolism intermediate between that of a lizard and that of a warmblooded living bird or mammal.

The Mesozoic rocks of Argentina continue to be fertile territory for the discovery of ancient birds. In the mid-1980s, the northwestern part of the Patagonian steppe yielded remains of yet another early member of the bird family. Named *Patagopteryx,* this animal was clearly not a flier—its wings were tiny—but a stout-legged terrestrial bird about the size of a rooster. A wealth of fossils has given us a detailed picture of the environment and the animals that inhabited this site some eighty-five million years ago. *Patagopteryx* lived among enantiornithine birds, large dinosaurs, crocodiles, and boa-like snakes in a temperate to warm, forested environment. However, as geologist Susana Heredia has pointed out, because the sediments that entombed most of the fossils are those of ancient sand dunes, such dunes must also have been a typical feature of the landscape.

Perhaps the most startling and controversial of the new discoveries was made in the remote heart of central Asia. Over the last five years, the American Museum's paleontologists and Mongolian scientists have explored the Gobi Desert for clues to the origins of birds and mammals. Our many days of windy, sandy, and someimes muddy searches have produced some true fossil treasures. One of these is he bizarre *Mononykus,* a primitive bird hat wandered the rocky steppes of central Asia seventy to eighty million years ago *see* “New Limb on the Avian Family Tree,” *Natural History,* September 1993). *Mononykus* had numerous, tiny teeth; stout, short forelimbs; and a long tail. Some of my colleagues have questioned he avian affinity of *Mononykus* (*see* “*Dia-ryma* Among the Dinosaurs,” page 68). Others regard it as a burrowing dinosaur nrelated to birds. Despite the significant differences between *Mononykus* and extant birds, anatomical details of *Mononykus* convince me that it is more closely related to living birds than is *Archaeopteryx.* Therefore, if we accept *Archaeopteryx* as a bird, we have to consider *Mononykus* as another member of the avian house. Although the actual function of the peculiar forelimbs of *Mononykus* remains a mystery, the idea of a turkey-sized creature digging a hole with forelimbs only slightly larger than those of a golden mole sounds about as reasonable as trying to shovel snow with a teaspoon. A more likely, but still speculative, scenario is that *Mononykus* used its claws to strip bark or perhaps stems from low-growing vegetation. Another startling finding was recently made by my Argentine colleague Fernando Novas, who discovered the remains of creatures akin to *Mononykus* in Cretaceous rocks in Patagonia. These are the first such specimens of close relatives of *Mononykus* found outside of central Asia.

The history of Mesozoic birds, from the ground-dwelling *Mononykus* and *Patagopteryx* to the flightless, diving hesperornithiforms to the flying, arboreal enantiornithines, is one of great diversification; some are different from others not only in their habits and habitats but also in their physiology. But the story of birds during the age of dinosaurs is also one of tremendous extinction. *Archaeopteryx, Patagopteryx,* hesperornithiforms, ichthyornithiforms, enantiornithines, *Mononykus* and its kin, along with other, less well known groups of birds, all disappeared during the Mesozoic, leaving no descendants. Only one group, which appeared in the fossil record only at the end of this era, survived and branched into the feathered populace of Venice’s Saint Mark’s Square and all other living birds.

The latest discoveries have thrown open the gates to a whole new realm of paleontological investigation. New findings, such as ancient birds from China and North Korea, have challenged the patriarchy of *Archaeopteryx* as the oldest bird. Even the assumption that primitive birds were necessarily warmblooded has been contradicted by new studies of bone microstructure. Most importantly, ongoing work in field and laboratory promises to expand our knowledge of the evolutionary history of the living dinosaurs.



The robin-sized Concornis *is an ancient enantiornithine bird recently discovered in central Spain.*

Courtesy of J. L. Sanz, Universidad Autonoma de Madrid

An Egg Thief Exonerated

by James M. Clark

On a summer day in 1923, in the fossil-rich region of Mongolia known as the Flaming Cliffs, George Olsen discovered an oblong rock that looked for all the world like a large egg. A member of the American Museum's Central Asiatic Expedition, Olsen took the expedition's leaders, Roy Chapman Andrews and Walter Granger, to the site, where several more of the eight-inch-long specimens, more elongate than typical birds' eggs, lay on the ground. After considering every possibility they could think of, the paleontologists concluded that they were fossilized dinosaur eggs—the first ever found. None of these eggs contained an embryo, but because fossil skeletons of the primitive horned dinosaur *Protoceratops* were so abundant in the Flaming Cliffs, the expedition members believed that the eggs must have been laid by this small, ubiquitous herbivore.

The nest was excavated and taken back to New York, along with a fossil skeleton that had been found lying over the eggs. As the sediments surrounding the skeleton were removed, the paleontologists were surprised to see that although it had the body of a theropod—the group of bipedal meat eaters to which *Tyrannosaurus* and *Velociraptor* belong—its skull was unusual. The typical theropod skull is long and low with many sharp teeth, but this head was short and stout, lacked teeth, and bore a hollow crest atop the snout. In life, this dinosaur would have stood about six feet tall and resembled a present-day cassowary—a large, crested groundbird of Australia. This new dinosaur needed a name. Its incriminating position above the eggs led Henry Fairfield Osborn, then president of the American Museum, to name it *Oviraptor philoceratops*, or "egg thief that loves ceratopsians." Yet Osborn presciently noted that the designation could "entirely mislead us as to its feeding habits and belie its character." Now another discovery in the Gobi Desert of Mongolia has indeed placed the egg thief in a new light.

Just a few days after the seventieth anniversary of Olsen's discovery (in the fourth year of the American Museum's renewed expeditions to the Gobi Desert in conjunction with the Mongolian Academy of Sciences), our team set out to explore a nondescript series of low hills in the Nemegt Basin, a region southwest of the Flaming Cliffs. We soon realized that this region, Ukhaa Tolgod (Mongolian for "brown hills"), contained the richest fossil beds any of us had ever encountered. Mark Norell, curator of dinosaurs at the Museum, had wandered on ahead of the group with expedition leader Michael Novacek, and they soon returned even more excited than when they had left. Norell led us to an outcrop and pointed to a dinosaur egg he had found lying on the ground. Half the fossil shell had eroded away, but curled within the remaining half was the skeleton of a tiny dinosaur. Before being fossilized, the bones had hardened, or ossified, indicating that this young dinosaur was close to hatching when it perished some eighty million years ago.

While fossil eggs have proved to be common in some places, embryos are rare. Until recently, nearly all known dinosaur embryos were those discovered by Jack Horner and his colleagues in northern Montana. These finds were mainly of two herbivorous dinosaurs: the hypsilophodont *Orodromeus* and the duckbilled *Maiasaura* (*see* "Dinosaur Eggs: The Inside Story," *Natural History*, December 1989). Our newfound Ukhaa Tolgod egg looked just like the eggs attributed years earlier to the plant eater *Protoceratops*, but the embryo bore the

The tiny bones of an oviraptorid inside the intact half of a shell, below, were discovered by the American Museum of Natural History's 1993 expedition to the Gobi Desert. The first embryo of a carnivorous dinosaur ever found, it was close to hatching at the time of its death. Its position in the egg is depicted in the reconstruction at right.

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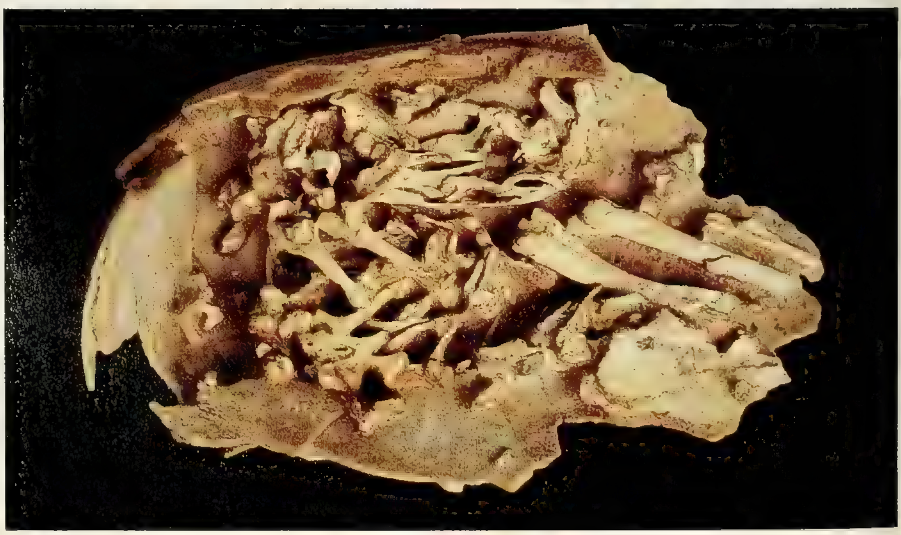


hallmarks of a carnivore rather than an herbivore. Its skull—often a clue to identity—was hidden in the sandstone in the egg, but the hip bones, which were visible, indicated that it was a theropod. Just a few inches from the egg, we found two sandstone nodules; each enclosed the tiny skull of a hatchling theropod reminiscent of *Velociraptor*. One of these even had eggshell adhering to it. This led us to think that the tiny inhabitant of our egg could be an embryonic *Velociraptor*.

At the end of the summer, we returned to New York eager to identify the embryo. In the lab at the American Museum, preparator Amy Davidson slowly removed the sandstone surrounding the tiny bones. Because the top half of the embryo's skull was missing, we were left with a confusing array of palatal bones to ponder. Just at the time that the lower jaw was being uncovered, Mongolian paleontologist Barsbold Rhinchen, the world's authority on *Oviraptor*, was visiting the Museum. After his analysis of this portion of the palate and jaw, we were sure that our embryo was not a *Velociraptor* but an oviraptorid (the group that includes *Oviraptor* and its relatives).

What the *Velociraptor*-like skulls were doing in the nest remains an enigma. Skulls this small of this rare animal had never been found before; their size indicates that they were the skulls of hatchlings or even embryos. While we can conjure up explanations for their presence, we have no way of determining which are more likely. What we can do now, however, is begin to answer the puzzle of which eggs at the Flaming Cliffs belonged to which animals. Of the many types of eggs found in this area, fully half, including the eggs discovered by Olsen, are just like the oviraptorid egg. They can easily be identified by their unusually elongated shape, the distinctive series of ridges and bumps on the outer surface, and peculiarities of the microscopic structure of the shell.

Recent studies by Polish and Russian paleontologists have questioned whether the first-discovered eggs were really those of *Protoceratops*, but unless an embryo is present within the egg, identifying the egg is largely a matter of conjecture. For example, the indirect association of the hatchling *Velociraptor*-like skulls with the Ukhaa Tolgod egg had at first led us to surmise that it might contain a *Velociraptor*. Another correlation that can lead to mistakes is using relative numbers of different animals in the fossil bed to determine identity, as when the most common egg type from the Flaming Cliffs was thought to belong to *Protoceratops*, the area's most common dinosaur.

Our discovery indicates that many of the Gobi eggs attributed to *Protoceratops* actually belong to oviraptorids. As if to demonstrate that such nesting is no fluke, a joint Canadian-Chinese team recently announced the discovery of a second nest associated with an adult oviraptorid skeleton. While some of the most intriguing questions about these creatures and their habits remain unanswered, our evidence alters Osborn's implications as to the "character" of *Oviraptor*. The "egg thief" from the Flaming Cliffs was more likely to have been sitting on the eggs than preying on them.

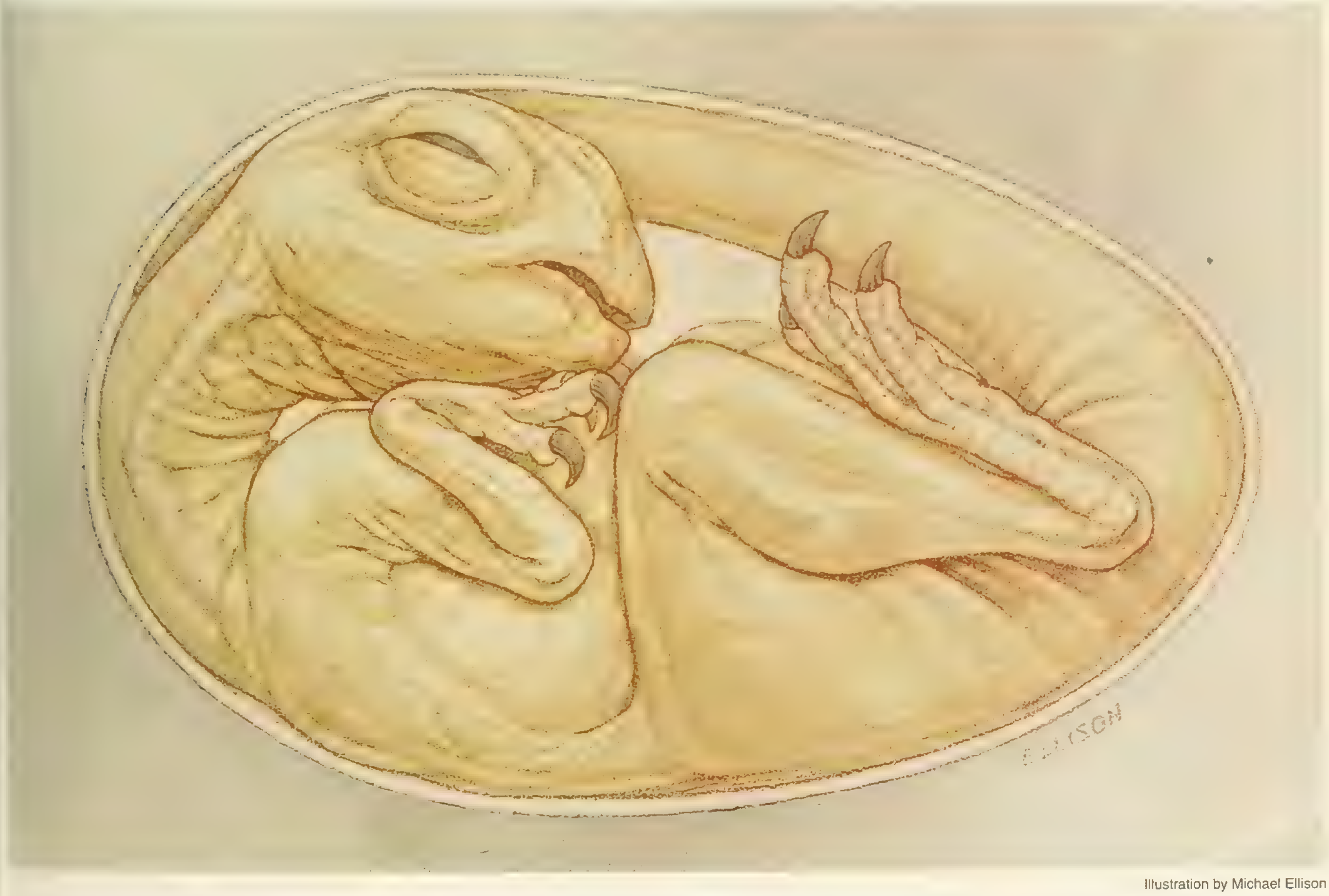


Illustration by Michael Ellison

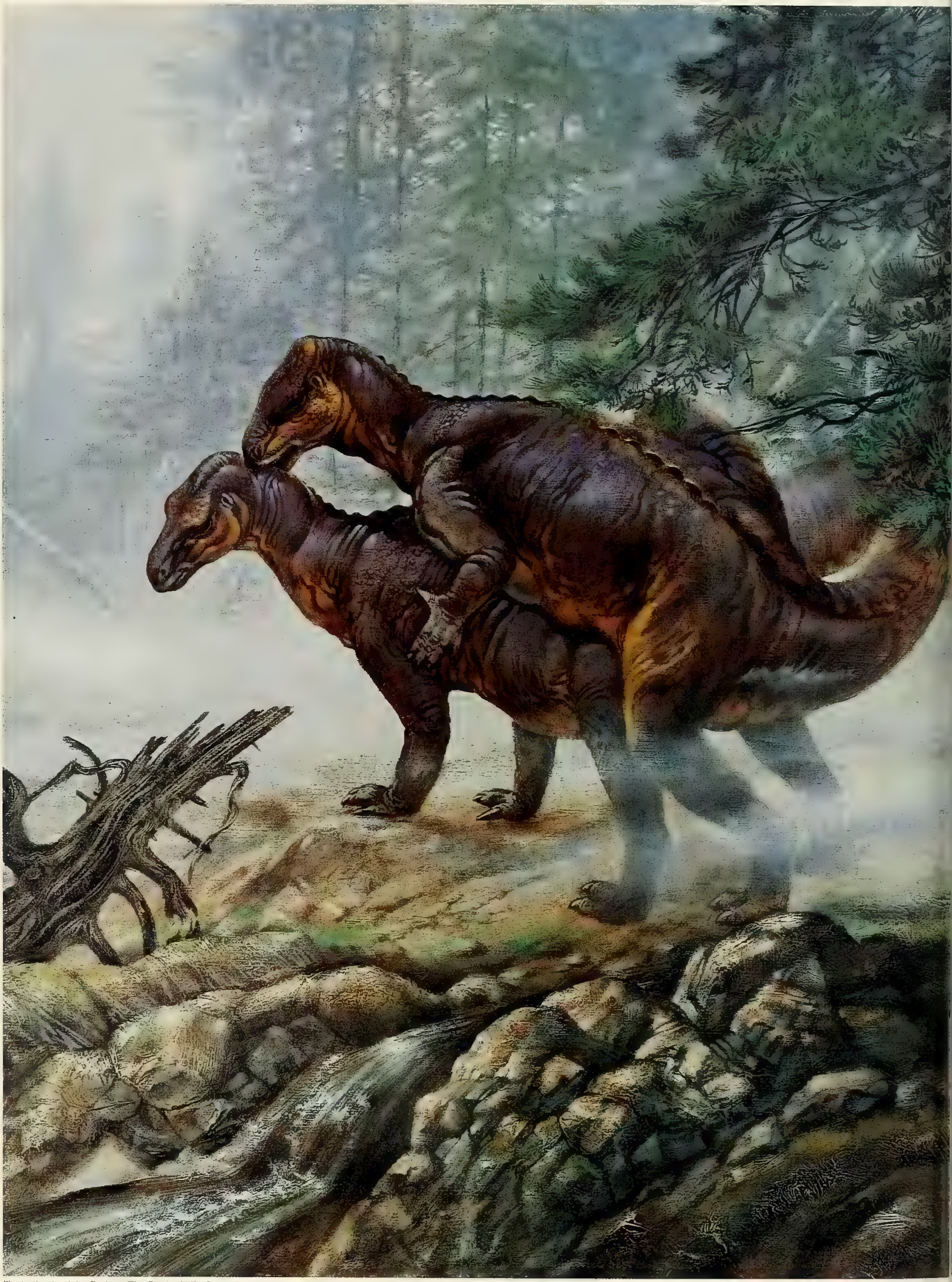


Illustration by John Barber; *The Book of Life*, Ebury Press, 1993

Origins of the Feathered Nest

by Mark Norell

To see birds as living dinosaurs goes beyond changing our outlook at our next Thanksgiving or fried chicken dinner. The theory that gave rise to the classification of birds as dinosaurs is based on their anatomical features, but it also enables us to think objectively about the behaviors of extinct dinosaurs. The theory can also help us interpret exciting new fossil finds, such as the oviraptorid embryo collected in 1993 in the Ukhaa Tolgod region of the Gobi Desert by paleontologists from the American Museum of Natural History (*see* "An Egg Thief Exonerated," page 56). One area of behavior related to this discovery—dinosaur reproduction—lends itself to interpretation.

While the reproductive habits of dinosaurs are a focal point for active imaginations and have elicited rampant speculation, such habits have not been the subject of much empirical scientific inquiry. Part of the problem is that direct evidence is hard to extract from the fossil record. An alternative pathway by which to explore paleontological private life is phylogenetics, or cladistics, where relevant observations are placed within a theory of evolutionary relationships. To do this, we identify specific attributes of the archosaurs, a group consisting of extinct dinosaurs and their living avian and crocodilian kin, including crocodiles and alligators. These data are then put in a phylogenetic perspective. I want to consider six specific areas of dinosaur reproduction in light of this theory: mating, egg laying, nest building, egg manipulation, nest defense, and incubation. First the data.

Mating. Among living archosaurs, the physical act of mating runs the gamut from the clumsy but effective gyrations of crocodilians to the gang-rape tactics of ducks to the in-flight romantic acts of swallows. In many amniotes (vertebrates that can reproduce on land because their eggs are sealed by the amnion, a watertight membrane that surrounds the developing embryo), mating is facilitated by a male intromittent organ. Crocodilians have a penis, and primitive living birds such as ostriches, rheas, and emus, as well as ducks and geese, also have a small penis. More advanced birds lack such an organ, and sperm is transferred from male to female simply by a pair placing their cloacal openings in contact.

The presence or absence (and obviously the size) of dinosaur penises has been much discussed. The only direct evidence that sheds light on this question involves differences in the pelvis and vertebrae at the base of the tail in members of single dinosaur species. Such differences are readily apparent in living crocodilians: in males, the haemal arches (small shafts of bone attached below the tail bones) start on the second vertebra behind the pelvis, while in females they start on the third. The shape of the haemal arches also differs between males and females. Dissection of the tail of these animals shows that males and females have different kinds and sizes of muscles that attach to the front of the haemal arch. Male crocodilians use these muscles to retract the penis into the body.

Do the bones of extinct dinosaurs hint at the same sorts of sexual differences? Because relatively few complete dinosaur skeletons that preserve these features have been excavated, our sample size is minuscule. But work on some dinosaurs, such as *Tyrannosaurus rex*, shows the same sort of variation seen in living crocodiles and may indicate male–female differences.

Egg laying. All living archosaurs lay eggs. The ability to bear live young has indeed evolved repeatedly in several different kinds of vertebrates, including guppies, rattlesnakes, and night lizards. Evidence of live birth is occasionally preserved in the fossil record, as in the spectacular specimens of Jurassic ichthyosaurs, which were marine reptiles. But we do not have a shred of evidence that any extinct dinosaur bore live young.

Nest building. Crocodilians and living dinosaurs (birds) build nests, and not surprisingly, so did extinct dinosaurs. Archosaur nests vary tremendously. Some, like those of alligators and many living birds, are elaborate structures made from vegetation. They reach an extreme in birds like some African weavers, whose communal nest can weigh in excess of 2,000 pounds. In contrast, the nests of primitive birds such as ostriches are simple, unadorned depressions in the ground, whose major purpose seems to be to keep the eggs from rolling away.

Fossilized dinosaur nests of many types and sizes have been found all over the world. Because plants and other nest materials do not often fossilize, the architectural details are not always preserved; however, an aggregation of whole fossil eggs is considered to be evidence of a nest. The most perplexing aspect of fossil nests is determining just what animal constructed them. Many, like some found in southern France, contain ten-inch-long eggs, laid in an arcing pattern in circular depressions up to five and a half feet in diameter. Similar eggs have been found elsewhere in local aggregations or even in parallel lines. At one of the best-known sites, Egg Mountain in the Cretaceous Two Medicine Formation of Montana, one- to two-yard-wide nests have been reported to look like miniature volcanoes.

Beneath Cretaceous conifers, a pair of Iguanodon *propagate their species. Fossil bones of a few dinosaur species hint at anatomy involved in the transfer of sperm.*

Manipulation of eggs. In contrast to crocodilians, most living birds, after laying their eggs, manipulate them into a definite, preferred orientation and continue to rearrange them throughout the brooding cycle. In many fossil dinosaur nests, the eggs are randomly placed, while in others, the eggs are arranged in a particular pattern unlikely to have formed during actual egg laying. These latter fossils are evidence that some extinct dinosaurs physically manipulated their eggs after they were laid.

Nest guarding. Most birds are attentive parents, defending the nest and provisioning the young. Less well known are the family habits of crocodilians, which also defend their nests and in some cases even dig the young out when they hear the high-frequency chirps the young make when they are about to hatch. These chirps are the same as the ultrahigh-frequency "pipping" of birds before they emerge from the shell. They are thought to be a sort of signal that helps synchronize hatching in a clutch of eggs.

Incubation. Most living birds incubate their eggs. This behavior is implicitly tied to the warmblooded metabolism of living birds, as the young need warmth to develop. Although speculation abounds, little in the way of fossil evidence bears directly on the possibility of brooding behavior in extinct dinosaurs. Volumes debating the pros and cons of warmblooded nonavian dinosaurs have been published, but as of now, no consensus has been reached. The closest thing we have to direct evidence is a couple of oviraptorid skeletons lying above nests.

How can a scientist make sense of all these data? One way is to apply the well-supported hypothesis that holds that dinosaurs (including birds) and crocodilians shared a common ancestor with each other more recently than either did with any other group of animals (for example, with lizards or mammals). Any characteristic that is found in crocodilians and birds is presumed to have been present in the unknown common ancestor of both crocodil-

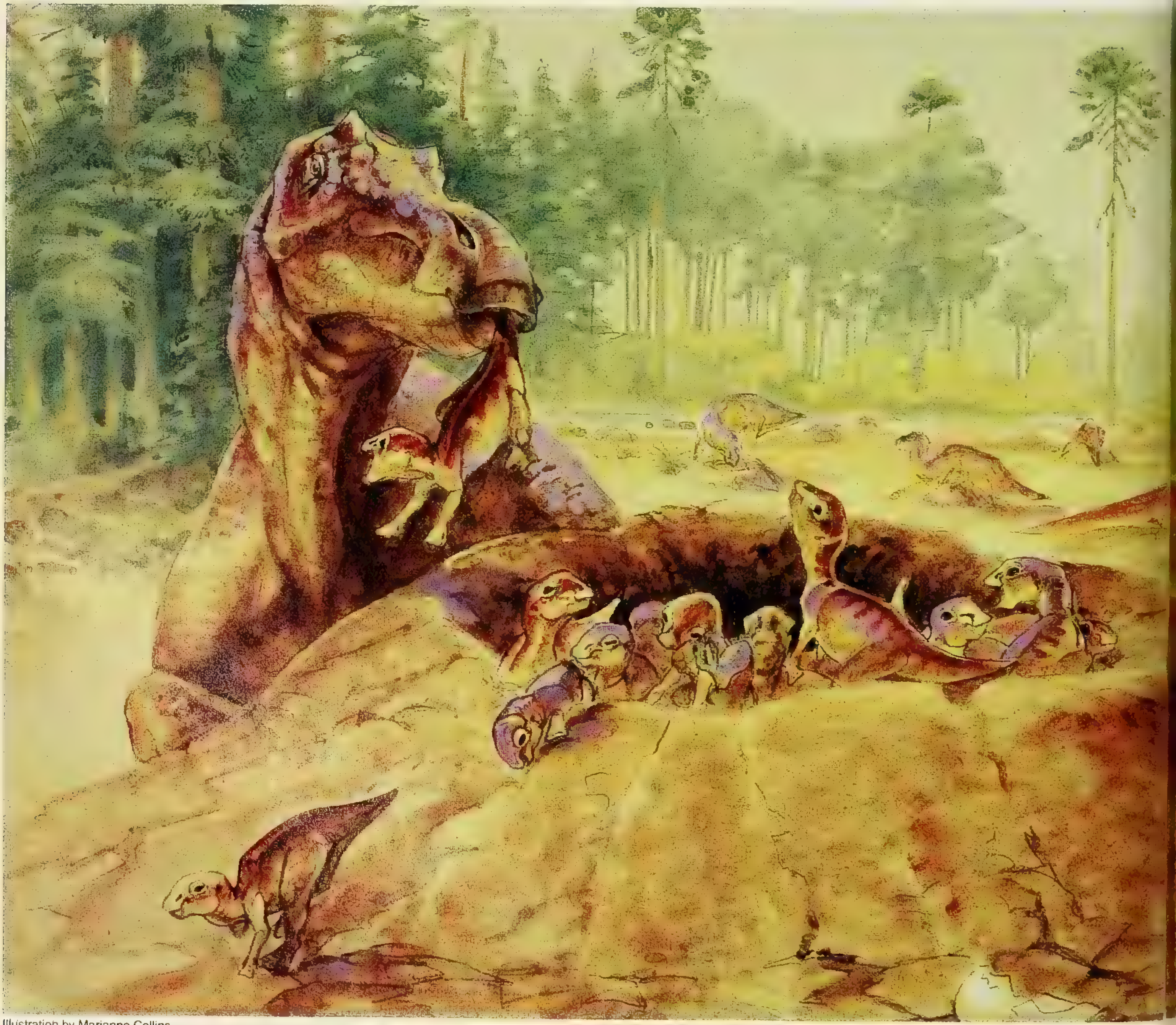


Illustration by Marianne Collins

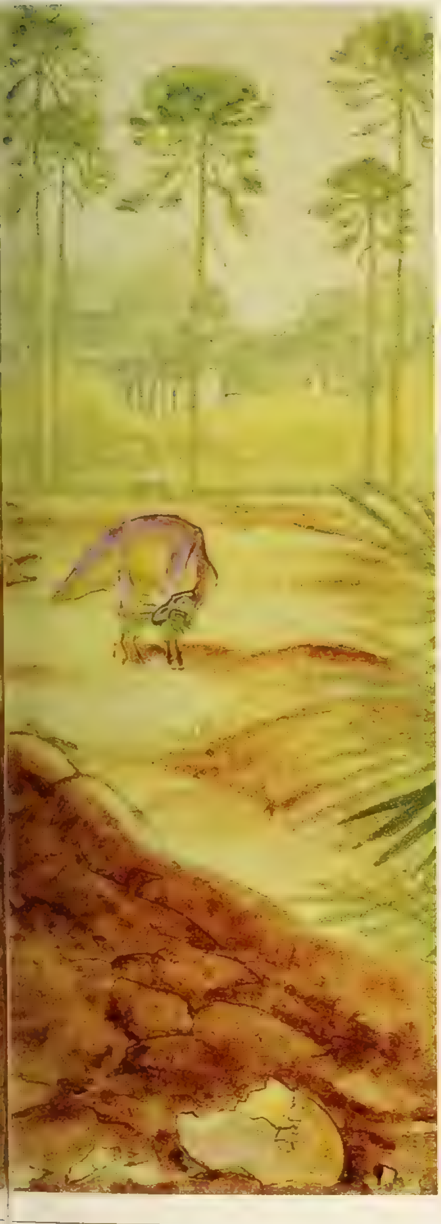
ians and birds. In the absence of contradictory evidence, these ancestral characteristics should also be present in all of the extinct members—both crocodilian and dinosaurian—of the group descended from this last common ancestor. This is the same line of reasoning that paleontologists use when they hypothesize that australopithecines, like Lucy, had hair. Because both our species and chimpanzees have hair, some sort of coiffure is thought to have been present in our common ancestor. No australopithecine fossils preserving evidence of hair have been found, but until we have contrary evidence, the simplest, and therefore the best, hypothesis is that Lucy had hair too.

We can use the same logic in interpreting the newly discovered oviraptorid embryo from Ukhaa Tolgod. Oviraptorids were small, bipedal dinosaurs closely related to birds. They, like other nonavian dinosaurs, are part of the great bush of archosaurian diversity that lies between the last common ancestor of crocodilians and all birds and the last common ancestor of living birds. We can predict that male oviraptorids had penises, that the females laid eggs in nests, that nests were defended, and that the young communicated with one another using ultrasound before hatching. The fossil evidence from the discovery allows us to test the predictions of nesting and egg laying. It also gives us insight into the origin of characteristics found in birds but not in crocodilians.

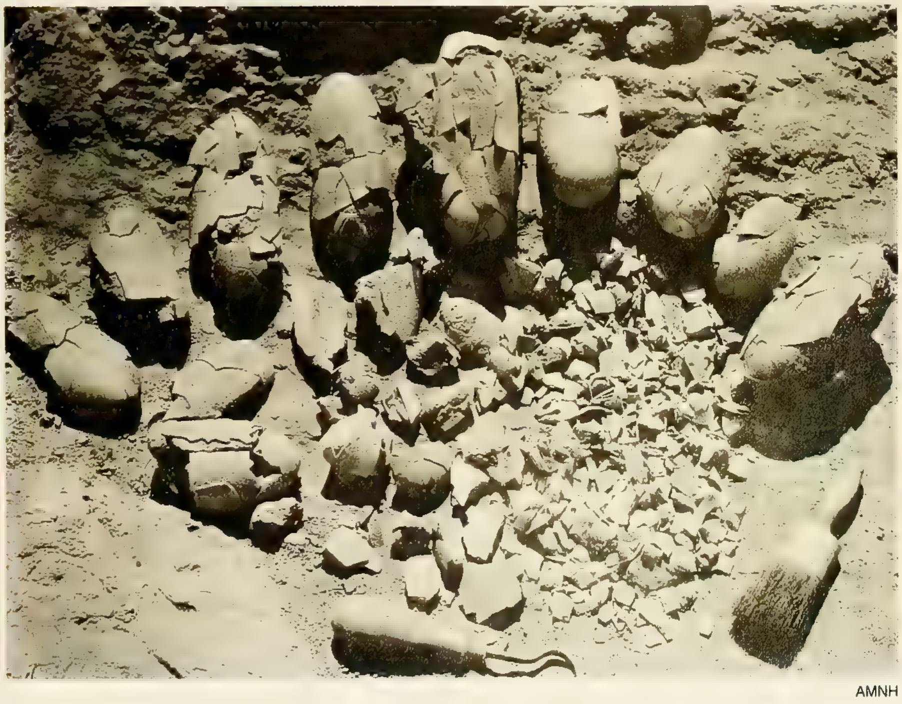
In the Ukhaa Tolgod and other oviraptorid nests, the eggs are arranged in a circular pattern, with the large end of the eggs facing inward. This indicates that, like modern birds, oviraptorids manipulated their eggs in the nest. More broadly, such evidence tells us that many of the behaviors that we think of as unique to birds have deep roots. They evolved far back within the history of the group, with the extinct nonavian dinosaurs.

Finally, some circumstantial evidence suggests that oviraptorid adults incubated their eggs. On two occasions, once during the Museum's 1923 expedition to the Gobi's Flaming Cliffs, and again during a recent Canadian-Chinese expedition on the Chinese side of the Mongolian frontier, adult oviraptorids have been found lying atop their nests. Although other explanations are tenable, these discoveries are consistent with the theory that adult oviraptorids were closely associated with their nests during life. Perhaps another fossil will provide the clinching evidence for the origin of brooding behavior in some nonavian theropod dinosaurs.

As paleontologists go into the field, bring back their finds, and try to understand more about animals of the past, spectacular fossils, like the oviraptorid embryo, grab the headlines. No matter how spectacular these fossils are, their scientific value can only be judged in the light of a good phylogenetic hypothesis.



A Maiasaura *tends its litter at a volcano-shaped nest, left. Like birds and crocodilians, nonavian dinosaurs are thought to have provided some parental care. Fossilized eggs in many dinosaur nests, like that of an oviraptorid, below, are arranged in patterns, indicating that eggs were turned after being laid.*



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Within the Bone

by Anusuya Chinsamy

When I first set eyes on a 190-million-year-old dinosaur bone under a microscope, I was astounded. Despite eons of burial and fossilization, the bone's microscopic structures were still intact. Apart from organic matter, such as cells and blood vessels, almost all the characteristics of modern bone were present: the channels that held the blood vessels, the tiny cavities that were once occupied by bone cells, even the minute channels that allowed communication between neighboring bone cells. My fascination was so great that I decided to change the focus of my research from the soft tissues and physiology of extant animals to the bones of dinosaurs. I hoped to be able to solve some of the mysteries of dinosaur biology.

The question of whether dinosaurs were coldblooded (ectothermic) or warmblooded (endothermic) has been a matter of fierce debate. Were they the dynamic creatures now often depicted in popular literature and the media, or were they classic, sluggish reptiles that lazed in the sun? Did they grow as fast as warmblooded mammals and birds, or did they take life at a leisurely pace, like coldblooded reptiles? What were their energy requirements, and how much food did they consume?

Various theories have been postulated regarding the thermal regimes and energy budgets of dinosaurs. These range from the anatomical—for example, hypotheses based on posture and limb support—to the phylogenetic, and, more recently, to theories based on oxygen isotope analysis. Contrary to various assertions, we have as yet no direct evidence for endothermy in dinosaurs, and their thermal biology remains in the realm of speculation. At the time I began my work, even dinosaur bone microstructure was being adduced as evidence for their endothermy. It soon became apparent, however, that no type of bone tissue is unique either to ectotherms or to endotherms.

Still, the microstructure of dinosaur bone has a tale to tell. During life, bone is a living tissue that records its own rate of formation. The type of bone tissue and its organization can indicate the processes or factors that affect its growth. Soon after an animal dies and is buried, the organic component of bone decomposes. The inorganic component, composed mainly of the mineral apatite, is more stable. By studying the organization of the apatite in sections of dinosaur bones about 30 microns thick (roughly half the thickness of a human hair) under a microscope, we can deduce whether bone formed rapidly, as in mammals and birds today, or whether it formed more slowly, as in modern reptiles.

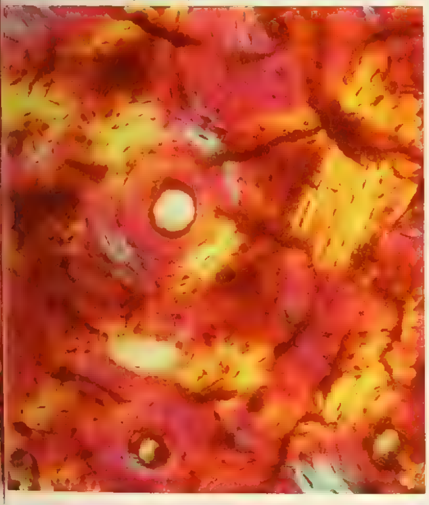
Studies of modern animals have shown that different rates of bone formation result in different bone types. A slow rate of bone deposition results in lamellar bone tissue, which typically has an ordered arrangement of collagen fibers. Rapid bone formation results in fibrolamellar bone tissue, in which the collagen fibers are haphazardly arranged and form a fibrous, or woven, bone matrix. During the rapid formation of this matrix, numerous blood vessels are entrapped and lamellar bone is deposited around each blood vessel, producing a feature called a primary osteon. Lamellar bone and fibrolamellar bone represent extreme slow and fast rates of bone formation; intermediate rates also occur.

Reptiles and amphibians are particu-

larly intriguing in having lamellar-zonal bone, which is characterized by growth rings formed by alternating regions of slow and fast bone formation. The region of fast bone formation is termed a zone, while the period of slow bone formation is called an annulus. Lines of arrested growth signaling a pause in bone deposition can occur before or after the annulus. Experimental studies using fluorochrome dyes have shown that the growth rings, roughly analogous to tree rings, are formed annually. By counting the rings, we can estimate the age of the reptile.

In the 1970s and early 1980s, paleontologists generally believed that most dinosaur bone consisted of highly vascularized fibrolamellar tissue with extensive concentrations of secondary osteons (structures formed by the removal and subsequent redistribution of bone around the vascular canals). These characteristics were thought to be typical of mammalian and avian bones, and their occurrence in dinosaur bone was cited as evidence of endothermy in dinosaurs. However, these histological features are now recognized to varying extents in typical coldblooded reptiles as well.

Furthermore, in 1981 University of Belfast paleontologist Robin Reid reported lamellar-zonal bone with at least seventeen growth rings in the pelvis of a sauropod dinosaur. This discovery demanded that we take a fresh look at dinosaur growth and biology. In 1990, Reid published a detailed review of his bone work, showing that growth rings could be found in several major groups of dinosaurs. Rather than growing quickly, as mammals and birds do, several kinds of dinosaurs evidently grew in periodic spurts, much as reptiles do today.



A section of Tyrannosaurus *bone, left, reveals deposits of fast-growing bone, rich in blood vessels, interrupted by rings indicating pauses in growth. Within the fast-growing bone of a femur of the stegosaur* Kentrosaurus, *below, slower-growing bone surrounds cavities that once housed blood vessels and nerves.*

Photographs by Anusuya Chinsamy

I examined the bone microstructure, or histology, of two species of early Jurassic dinosaurs whose fossil remains are relatively abundant in southern Africa. One was the 190-million-year-old prosauropod *Massospondylus,* an early quadrupedal plant eater; the other, contemporary with the first, was the theropod *Syntarsus,* a bipedal meat eater. I was fortunate to obtain a growth series—specimens of progressively more mature individuals—for each dinosaur. Since the closest living relatives of dinosaurs are crocodiles and birds, I also analyzed the bone microstructure of the Nile crocodile, the secretary bird, and the ostrich. I hoped that histological comparisons of the bones of extant animals with the fossil specimens would provide clues to the physiology of the two dinosaurs.

I found that the overall stratification of the compact dinosaur bones had distinct growth rings and did indeed look reptilian. But upon closer inspection, I found that the period of fast growth consisted of fibrolamellar bone, that is, the kind of bone typically found in mammals and birds. Thus, both *Massospondylus* and *Syntarsus* bone had a mosaic of both reptilian and mammalian characteristics. The number of growth rings increased with the size of the animals, so I speculated that as in modern reptiles, these rings were formed annually. I calculated that the medium-sized, 45-pound theropod *Syntarsus* took some seven years to reach a mature body size, whereas the 550-pound prosauropod *Massospondylus* took about fifteen years. In another study of bone microstructure, paleontologist David Varricchio, of the Musuem of the Rockies, showed that the 110-pound theropod *Troodon* took between three and five years to reach maximum size.

My recent postdoctoral work at the University of Pennsylvania has involved a study of the growth series of *Dryosaurus,* a plant-eating ornithopod from the renowned Tendaguru beds of Tanzania. *Dryosaurus* was peculiar in that none of the bones showed any sign of slowed growth or lines of arrested growth. I thought perhaps this was because of the warm, equable environment in which the dinosaurs of the Tendaguru lived, until I found that the bones of the stegosaur *Kentrosaurus,* from the same deposits, had clear growth rings. Working independently in Texas, paleontologist Dale Winkler reported that a growth series of ornithopods from Proctor Lake also showed continuous, rapid bone formation with no growth rings, whereas the bones of several other dinosaurs from the same deposits did have growth rings. Thus, *Dryosaurus* and the Proctor Lake ornithopods appear to have been capable of a sustained, rapid rate of growth, not because they enjoyed a mild climate, but because they differed physiologically from their contemporaries.

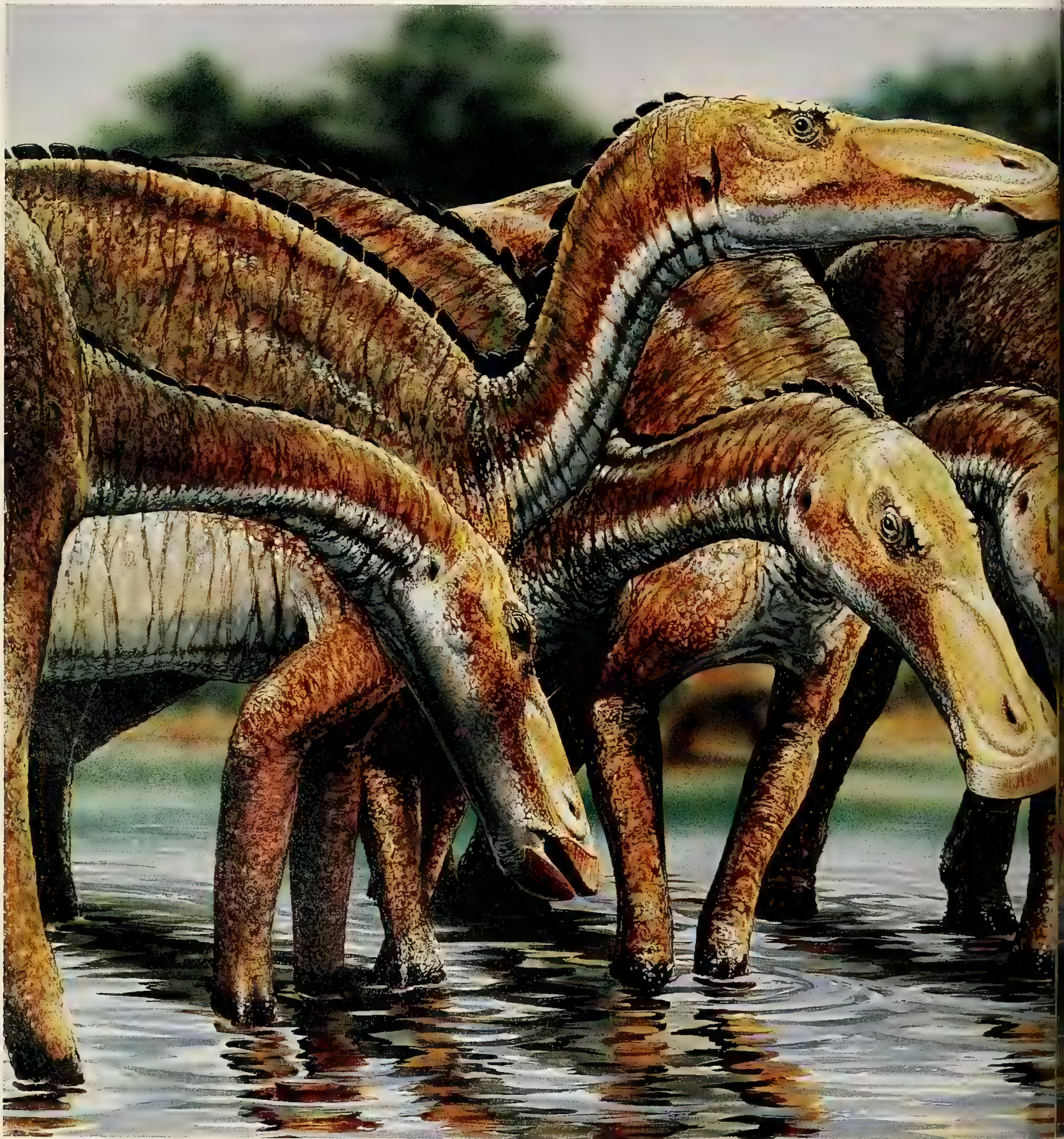
Did dinosaurs, like reptiles, continue to grow throughout their life, or did they stop once they reached a particular, mature body size, as mammals and birds do? On the basis of the nature of the bone formed late in their growth, some dinosaurs, including *Syntarsus, Brachiosaurus, Troodon,* and *Iguanodon,* appear to have reached a definite, mature body size and then stopped growing. Even the largest *Dryosaurus* and *Massospondylus* individuals, in contrast, appear to have been still growing when they died.

Recently, paleontologists Luis Chiappe, of the American Museum of Natural History, Peter Dodson, of the University of Pennsylvania, and I studied growth rings in some Cretaceous birds (*see* "A Diversity of Early Birds," page 52). We found that birds such as *Patagopteryx* and the enantiornithines were incapable of growing at a sustained, rapid rate and were therefore physiologically different from modern birds. We proposed that birds developed full endothermy later in their history and did not inherit it from their nonavian dinosaurian ancestors.

Studies of the bone histology of birds, extinct dinosaurs, and living animals has given us new insight into the biology of ancient animals, and I look forward to broadening my investigations. We now recognize that no unique growth pattern, or physiology, characterizes all dinosaurs, and that rapid rates of growth appear to have evolved independently several times in the Dinosauria.

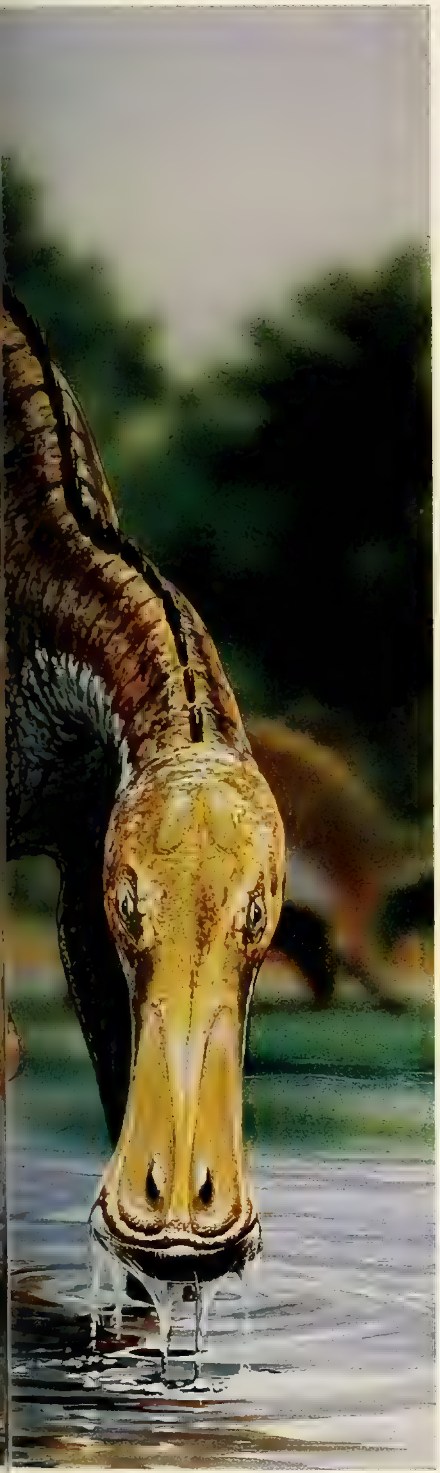
Designer Jaws

by David B. Weishampel



Early in the history of life on land, vertebrates primarily consumed fish, insect delicacies, and one another. A snap of the jaws and a swallow or two was all it took to turn prey into a meal. When vertebrates finally began to eat plants about 300 million years ago, they probably did so in a fairly uncomplicated fashion, puncturing and tearing with simple, peglike teeth.

But life as an herbivore requires some specializations. To break through the tough cell walls of plants and extract nutrients, vertebrates—including ourselves—depend upon colonies of microbes known as gut flora. Inhabiting the dark recesses of digestive tracts, these microbes secrete particular enzymes (otherwise lacking in vertebrates) that break down cell walls and liberate the internal nutrients. Herbivores can speed the activities of the microbes by providing them with food particles that have considerably more surface area on which chemical digestion can work. They do this by grinding leaves, stems, and fruits into bits, that is, by chewing.



A herd of Anatotitan, *duck-billed hadrosaurids inhabiting late Cretaceous North America, finds refreshment in a shallow stream.*

Illustration by Donna Braginetz

At least by the beginning of the Mesozoic, some 245 million years ago, plant eaters had developed ways of chewing that eventually led to the styles of mastication found in many modern plant-eating mammals. Of these, fore–aft chewing is found today in rodents and elephants, while side-to-side, or transverse, chewing characterizes the ungulates—hoofed mammals, from horses and rhinos to cows and camels. The trick to transverse chewing lies in having room for the jaws to slide side to side. This requires that the distance between the sides of the lower jaw be less than that between the sides of the upper jaw, a condition known as anisognathy, or "unequal jaws." (Isognathy, or "equal jaws," is the condition found in all other land vertebrates.) Anisognathy may well have been of evolutionary importance to ungulates, which throughout their history have been among the most diverse of all medium- to large-bodied plant eaters.

But it is another diverse group that has intrigued me most: the herbivorous dinosaurs of the Mesozoic. Dinosaurian plant eating evolved in two major groups. The sauropods and their predecessors, the prosauropods, which make up one group, seem to have nipped vegetation from tall trees. Despite their rather rudimentary teeth, they processed great quantities of foodstuffs, sometimes with the aid of stomach stones, or gastroliths (*see* "True Grit," page 41). The ornithischians—stegosaurs, ankylosaurs, pachycephalosaurs, ceratopsians, and ornithopods—were the other great dynasty of dinosaurian herbivores. Early on in the evolution of this group, chewing appears to have been rather simple, probably consisting of little more than repetitive puncturing and pulping of foliage with simple, triangular teeth. One can imagine the likes of a *Stegosaurus,* an armored *Euoplocephalus,* or the dome-headed *Stegoceras* slowly nibbling on succulent leaves or perhaps low-lying fruits, unhurriedly selecting their fodder.

Ceratopsians and ornithopods, however, were capable of much more specialized chewing. The ceratopsians, or horned dinosaurs, were plant-eating quadrupeds that ranged from some six to twenty-five feet long. They used their parrotlike beaks to snap up leaves and branches, and chewed by slicing and dicing with their large, closely packed teeth. Vegetation grasped between the near-vertical chewing surfaces of the teeth would have been sheared apart in the same way paper is sliced by scissors. Leaves, stems, and even small branches would have been reduced to something akin to matchsticks and angular confetti by repeated cycles of mastication before being swallowed.

Ornithopods, which ranged in size from the six-foot-long *Heterodontosaurus* to the thirty-foot-long *Maiasaura,* were bipedal herbivores. Like ceratopsians, they too had closely packed chewing teeth, but by the time hadrosaurids evolved, the dentition consisted of relatively small teeth that were organized into a complex battery, all the better for grinding up vegetation. Ornithopods also differed from ceratopsians and other ornithischians in having relatively low-angled chewing surfaces on their teeth. Scratches on their fossilized teeth indicate that they chewed with a side-to-side action, superficially like the kind of chewing found in ungulates. But their jaws reveal no sliding room that would be the case in anisognathy. How then did their jaws operate?

Dave Norman, of Cambridge University, and I independently set out to resolve this paradox of transverse chewing and isognathy. Beginning with a comprehensive study of *Iguanodon,* the second dinosaur ever discovered and still the best-known charter member of Dinosauria, Dave figuratively and sometimes literally dissected skulls of this early Cretaceous herbivore to see how the jaws worked.

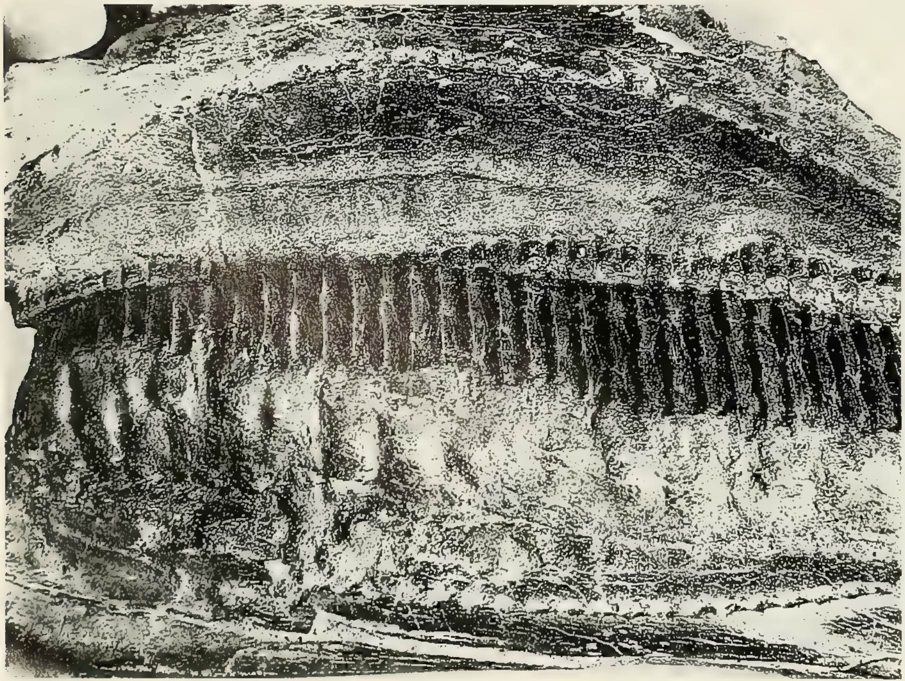
My approach was different. Instead of focusing on a particular ornithopod and working out the details of how it chewed from bones and reconstructed muscles, I examined skulls using what is known as three-dimensional kinematic analysis, a technique borrowed from mechanical engineering. Treating skulls as if they were "chewing machines," I was able to "manipulate" individual elements of the skulls of *Iguanodon* and a host of duck-billed dinosaurs, hypsilophodontids, and heterodontosaurids through computer-based kinematic modeling. I would begin by modeling the skull of one of these herbivores, say *Corythosaurus,* in three-dimensional space, emphasizing the locations and kinds of cranial joints I wanted to "move around." Using computers, I was then able to select various bones of the skull and move them in cyberspace (paleocyberspace?) to simulate chewing. The computer's versatility allowed me to make predictions not only about how individual parts of the skulls may have moved during mastication but also about how the upper teeth moved against the lower teeth. The latter aspect of my kinematic analyses appealed to me the most, because where there is tooth-to-tooth or tooth-to-food-to-tooth movement, there is wear on the chewing surfaces of the teeth themselves. This wear gives information on the direction of chewing movement, like the tracks of ice skates pointing in the direction the skater went. Tooth wear was the ultimate test for any given jaw mechanics model or hypothesis. A model would succeed only if it did not contradict evidence found in actual sets of fossil teeth.

The only two mechanisms to survive tooth-wear testing were an unusual jaw mechanism that allowed the upper jaws to slightly rotate laterally, found in hypsilophodontids and iguanodontians (hadrosaurids, *Iguanodon,* and close relatives), and another involving slight rotation of the lower jaw, found only in heterodontosaurids.

I was gratified to learn that what I had come up with through computer modeling was also what Dave Norman had determined in his work on *Iguanodon:* the sideways mobility of the upper jaws allowed the animal to chew on both sides at the same time. Dave called this kind of intracranial mobility pleurokinesis. We both recognized that this jaw mechanism gave both hypsilophodontids and iguanodontians the ability to chew transversely even though they were isognathous, that is, the sides of their upper and lower jaws were the same distance apart.

No living animals have anything close to this kind of chewing, and both Dave and I started to look for ecological clues that might shed light on its development. We imagined that ornithopods of any kind fed on a great variety of vegetation. Given the cropping end of the snout, these herbivores most likely indiscriminately chomped down on ferns, conifers, cycads, and other kinds of foliage and plant structures. Indeed, in the few cases where we have a record of stomach contents or coprolites (fossil dung), this is exactly what we see—a mixture of plants and plant parts (*see* "Lessons from Leavings," page 67). But more interesting still, the beginning of the heyday of pleurokinesis among ornithopod dinosaurs was nearly coincident with the rise of flowering plants. Sometime in the early Cretaceous, these ancestral angiosperms started out as rapidly growing shrubs and would have been perfect fodder for the kinds of sophisticated chewing mechanisms that were being tried out by ornithopods. Flowering plants could also have been enjoyed by the slicing-and-dicing ceratopsians, and perhaps even the less formidable chewers among dinosaurs, the Cretaceous ankylosaurs and pachycephalosaurs, which may have supplemented their cycad and conifer fare with the occasional flowering plant.

Possible connections between the rise of angiosperms and new ways of chewing in a diverse and thriving group of dinosaurs will continue to be explored. Perhaps we will find that angiosperms and dental sophisticates like the ornithopods were inextricably linked in a paleoecological bond between fodder and feeders.



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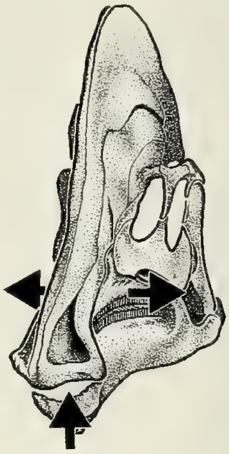


Like modern hoofed mammals, duck-billed dinosaurs such as Corythosaurus, *above, chewed with a side-to-side motion. Unlike today's ruminants, however, they derived the skill from a slight lateral mobility of the upper jaws (see horizontal arrows). Such dinosaurs were also equipped with an efficient battery of cheek teeth, left.*

Illustration by David Weishampel

Lessons from Leavings

by Karen Chin

Many people are surprised when they earn that I study fossilized feces. "Whatever for?" is their unspoken question. I earned the informative value of scat during my tenure as a naturalist for the National Park Service. Wild animals are usually very shy, so finding dung is often the next best thing to observing the animal itself. Park visitors on my guided nature hikes were bemused at my delight in finding animal feces, until I explained that such calling cards can provide important information about an animal's feeding habits and distribution.

Extinct animals are certainly more elusive than living ones, and when I began to study paleontology, I hoped fossil dung would be similarly informative. Unfortunately, fossil feces, known as coprolites, are more enigmatic than fresh fecal material. Biological and geological processes have altered the original contents—sometimes beyond recognition. This complicates dietary interpretations and can make it difficult to identify coprolites in the first place. Furthermore, the detached nature of feces makes it nearly impossible to match a coprolite with its maker. Despite these drawbacks, I was quite excited when paleontologist Jack Horner, of the Museum of the Rockies, told me that he had found some probable dinosaur coprolites in the badlands of Montana. I was working for Jack at the time, making histological secions of fossil bone. This technique prepares ultrathin slices of fossils so they can be examined microscopically. I asked if I could slice the purported coprolites as well, and my work on fossil dung began.

Coprolites more than a couple of million years old have usually been preserved hrough mineralization, that is, they have urned into rock. This means that such disinguishing characteristics as color and general appearance are not always reliable clues for confirming a fecal origin. Nevertheless, the first fossil feces were identified on the basis of shape and composition by British geologist William Buckland in the 1820s. Since that time, many other coprolites have been recognized, usually by their distinctive fecal shapes. Form, however, can be a misleading criterion when applied to variable soft material that has been altered over millions of years.

The specimens Jack discovered are full of plant fragments but have blocky shapes unlike other described coprolites. Some of the blocks are also large, measuring more than 13 by 13 by 9 inches. Jack suspected that the blocky aggregations of plant material were the fossilized feces of some of the Cretaceous dinosaurs whose bones he was finding in the same sediments. I began to analyze the specimens for evidence that could test the hypothesis that these blocks were indeed dinosaur droppings.

Microscopic examination of the thin sections I made revealed that the blocks are composed predominantly of small pieces of conifer stem tissue. The chopped-up nature of the plant material resembles the chewed residues found in the feces of living plant-eating animals such as horses and elephants. Other evidence supporting a fecal origin includes the sporadic distribution of the aggregations and their proximity to other dinosaur fossils. Bones and eggshells indicate that plant-eating duck-billed dinosaurs were common visitors to the area.

But the evidence that clinched the case for coprolites came from burrow traces left by some previously unheralded participants in Cretaceous ecosystems. Conspicuous burrows ranging from one-sixteenth of an inch to more than one inch in diameter pockmark many of the blocks. Some of these burrows are open tunnels; others show that plant tissue had been backfilled into burrows in the original adjacent soil, which was sometimes preserved along with the plant material. I suspected that the burrowers had been dung-eating beetles, but I couldn't verify that they were the perpetrators until I consulted Canadian entomologist Bruce Gill, who has studied many living dung beetle species. We found that the burrows in the blocks have many of the same characteristics of modern dung beetle burrows. The most diagnostic feature is the presence of large, backfilled burrows; dung beetles are the only living organisms known to cache plant matter into such sizable burrows. Thus, these burrow traces of ancient dung beetles helped confirm that the blocks are indeed coprolites.

We know that these coprolites were produced by plant-eating dinosaurs; other possible Cretaceous herbivores, mammals, for example, were simply too small to have produced dung in such quantities. The value of these specimens lies in the information they provide on the diets and ecology of dinosaurs. Although digestion, decomposition, and geological changes significantly altered the composition of the feces, recognizable plant tissues in the specimens indicate that these dinosaurs browsed on conifer stems. The coprolites also reveal an ecological link between dinosaurs and dung beetles. The beetles capitalized on the success of herbivorous dinosaurs by utilizing their copious wastes, and this recycling activity in turn benefited other organisms. A similar dung-based ecological web exists today in Africa, where dung beetles exploit elephant feces.

While the roles of dinosaurs in Mesozoic ecosystems have long been a subject of speculation, fossil evidence of dinosaur interactions with other organisms is rare. Thus, these humble pieces of fossil dung are particularly significant because they provide us with a brief glimpse of Cretaceous ecosystem dynamics.

Diatryma Among the Dinosaurs

by Allison V. Andors

Some 120 years ago, the first fragmentary fossil remains of an extinct giant bird surfaced in 55-million-year-old Eocene rocks in northwestern New Mexico. But not until 1916, when the first relatively complete skeleton came to light, could the imposing dimensions of this creature, known today as *Diatryma,* be fully appreciated. Excavated for the American Museum by fossil collector William Stein in northern Wyoming's Bighorn Basin, the skeleton was scientifically described by paleontologists William Diller Matthew and Walter Granger in 1917. Standing some seven feet tall and weighing perhaps 385 pounds, *Diatryma* had a huge head, an enormous beak, a thick neck, puny wings, a broad pelvis, and stout legs. *Diatryma* remains have since been collected at more than fifty early Eocene sites in the United States and Arctic Canada and at several early and middle Eocene localities in western Europe. Terrestrial and flightless, *Diatryma* evidently dispersed between North America and Europe across a transitory, high Arctic land bridge that existed during the early Eocene, before rifting severed the connection.

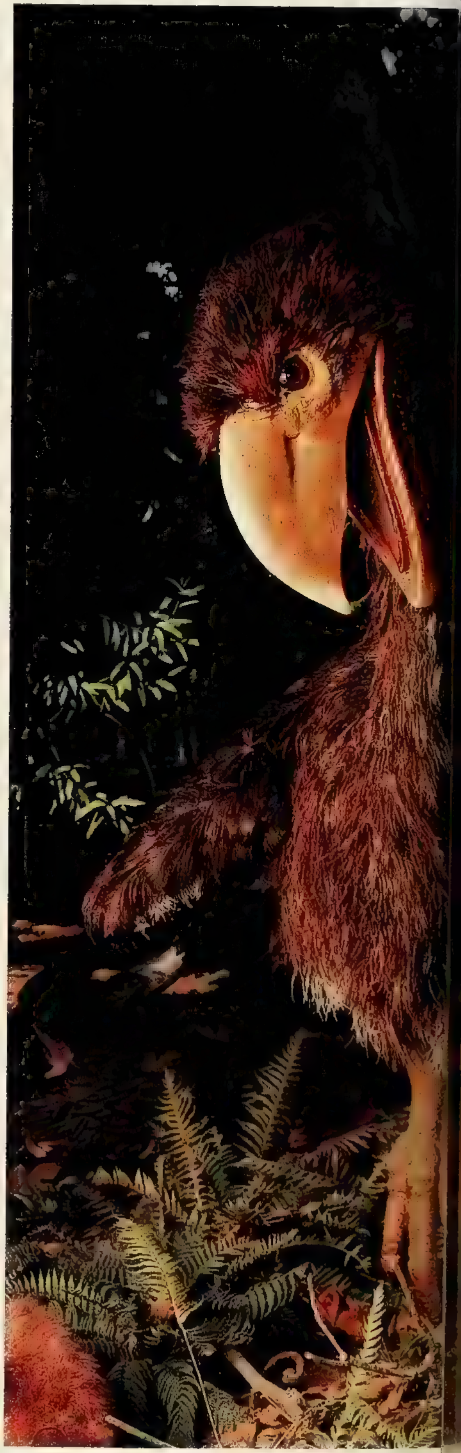
The sedimentary deposits in which *Diatryma* has been found, as well as the plants and other animals associated with it, suggest that this bird lived in habitats as varied as lush riparian woodlands, coal swamps, forested lake margins, coastal marshes, and relatively open savannas. The climate throughout its geographic range was temperate to subtropical. Although the Canadian Arctic was mild during the early Eocene, at an estimated latitude of 78 degrees, *Diatryma* would still have been subjected to a subpolar regime of long, dark winters and of summer nights illuminated by the midnight sun.

Ever since its discovery, scientists have attempted to determine how *Diatryma* may have lived and how it is related to other birds. *Diatryma* has been variously classified as an ally of ratites (the group that includes the living ostriches and rheas), ducks, parrots, South American seriemas, and rails, and as a "colossal heron."

In 1988, on the basis of a detailed study of New World specimens, I concluded that *Diatryma* is most closely related to the order comprising waterfowl (ducks, geese, and swans) and screamers (fowllike South American relatives of waterfowl). This affinity was suggested by shared cranial specializations and by such shared postcranial features as the inflected lower end of the tibiotarsus, or shank, which must have given the living *Diatryma* a somewhat bowlegged appearance. By comparing structures of the lower jaw and quadrate—the bone by which the mandible in all birds is movably articulated to the braincase—I found that *Diatryma* was also related, although more distantly, to the order of true fowl, the group that includes chickens. Recent DNA-DNA hybridization experiments conducted at Yale University by Charles G. Sibley and Jon E. Ahlquist confirm the affinity between the waterfowl and fowl orders. Put simply, in the avian family tree, *Diatryma* occupies a middle ground between ducks and chickens.

What does a 385-pound bird eat? Traditionally, *Diatryma* has been depicted as a fleet-footed predator, or "terror crane," analogous to the gigantic phorusrhacoids. The phorusrhacoids—a diverse assemblage of mostly large, ground-dwelling, predatory or scavenging birds with relatively large heads, strongly hooked bills, and relatively reduced wings—inhabited South America throughout the Tertiary. Flightless representatives of this extinct group evidently colonized North America after that continent was joined to South America by a Panamanian land bridge about three million years ago.

One theory holds that *Diatryma* in the

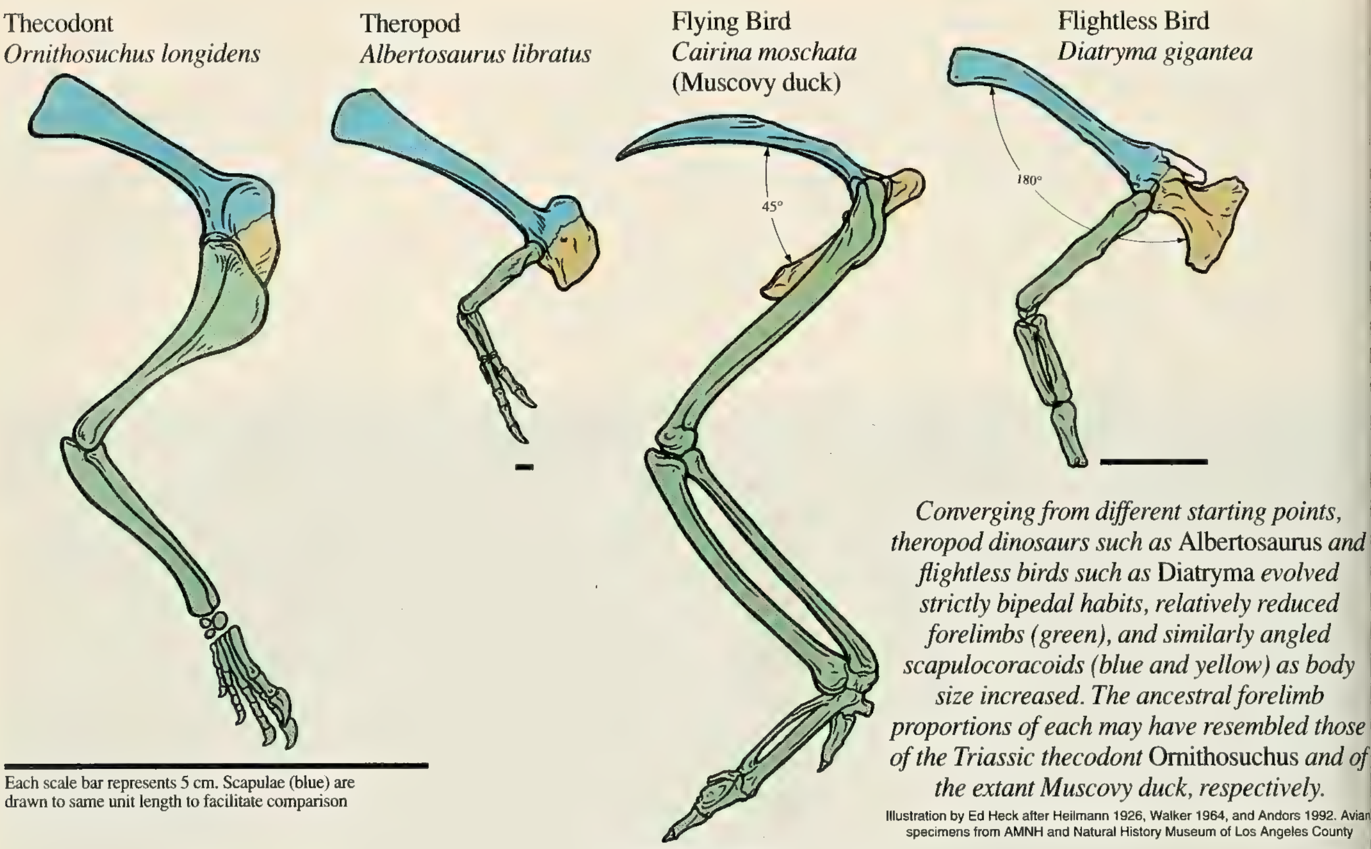


orth and phorusrhacoids in the south invaded the ecological niches left vacant by he extinction, 65 million years ago, of the nonavian theropods, or bipedal carnivorous dinosaurs, such as *Tyrannosaurus* see “Play It Again, Life,” *Natural Hisory,* February 1986). However, when I analyzed the jaw and hind limb mechanics of *Diatryma,* I found only part of this scenario to be valid. Whereas phorusrhacoids were apparently mostly predatory and successfully radiated into various carnivore niches in South America and elsewhere, *Diatryma* was no terror crane, having possessed neither the adaptations of a predator nor an affinity with cranes.

The jaws of *Diatryma,* although massive, lacked the pronounced hook typical of raptors, or birds of prey. The huge beak was apparently adapted for crushing and slicing the rank vegetation that cloaked the warm temperate and subtropical forests, marshlands, and wet savannas of Eocene Euramerica, and it was perhaps used only

In a reconstruction at the California Academy of Sciences in San Francisco, a pair of Diatryma *tend their young at the edge of an early Eocene North American forest. The new Hall of Saurischian Dinosaurs at the American Museum in New York features a replica of an unusually complete* Diatryma *skeleton in the Museum's collection.*

Susan Middleton; California Academy of Sciences



Each scale bar represents 5 cm. Scapulae (blue) are drawn to same unit length to facilitate comparison

Converging from different starting points, theropod dinosaurs such as Albertosaurus *and flightless birds such as* Diatryma *evolved strictly bipedal habits, relatively reduced forelimbs (green), and similarly angled scapulocoracoids (blue and yellow) as body size increased. The ancestral forelimb proportions of each may have resembled those of the Triassic thecodont* Ornithosuchus *and of the extant Muscovy duck, respectively.*

Illustration by Ed Heck after Heilmann 1926, Walker 1964, and Andors 1992. Avian specimens from AMNH and Natural History Museum of Los Angeles County

secondarily in scavenging carrion or in preying on the small mammals or reptiles that also abounded in these habitats. The proportions of the hind limb—especially the foot, with its relatively short tarsus, three stout front toes, and slender, functional hind toe—differ markedly from leg and foot proportions of open-country runners such as ostriches and rheas, which have achieved a longer, faster stride through evolutionary elongation of the tarsus, and which have reduced frictional contact with the ground through reduction in the number of toes to two (ostriches) or three (rheas). Hind limb proportions suggest that although *Diatryma* may have been capable of brief bouts of running, its characteristic gait was probably a walk. The shallow curvature of the claws of its toes indicate that the foot of *Diatryma* was better suited for ground activity, such as walking or occasional running, than for perching or for grasping prey.

Ornithologist George E. Watson and I have suggested that the closest modern analogue of *Diatryma* is the takahe, a flightless bird of remote subalpine grasslands of New Zealand's South Island. This four- to seven-pound rail has a *Diatryma*-like beak, a stout neck and legs, and short tarsi and toes; it is the largest living rail and feeds almost exclusively on grass. Other possible analogues of *Diatryma* include its closest living relatives, the three species of screamers, which inhabit riverside forests, marshlands, and wet savannas of northern South America. Screamers are also relatively large (six to eight pounds) and mainly herbivorous.

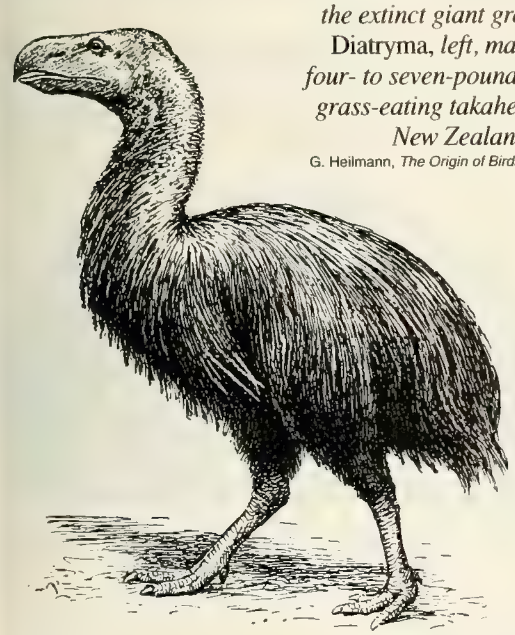
Large body size in *Diatryma,* the takahe, and other avian herbivores seems to have evolved in association with flightlessness and folivory, or leaf eating. Leaves are a low-energy food that, in order to be used efficiently, must be eaten in bulk and retained for a long time in a roomy storage space in the alimentary canal. The added weight, long retention time, and slow energy release of a leafy diet are disadvantageous to flying animals, which need to quickly extract energy from their food. Those few avian species that feed on leaves have accordingly tended to forfeit the energetic expense of flight and have evolved large size and relatively short forelimbs. Exceptions include the South American hoatzin, a one-and-a-half-pound folivore that has remained small and retained some flight capability by evolving ruminantlike foregut fermentation (*see* "A Bird with the Guts to Eat Leaves," *Natural History,* August 1991). The three species of flightless, two- to eight-pound New Zealand kiwis have also remained relatively small, but in marked contrast to the hoatzin, they have accomplished this by adopting a nutritious diet of mainly earthworms and other invertebrates, obtained by probing the soil and leaf litter with their long, snipelike bills. Their presumed closest relatives, the extinct New Zealand moas, were almost entirely herbivorous; not surprisingly, these were wingless and most were huge.

Reduction in relative size of the forelimbs in *Diatryma* and in other strict bipeds seems to be an evolutionary consequence of increased body size. When the forelimbs lose their locomotory function, a biped no longer has to maintain a favorable (in the case of birds, an aerodynamic) ratio of forelimb size to body mass, and through natural selection, body size can then increase, in some instances to a startling extent. This explains why the most ponderous birds tend to have the shortest wings in proportion to their mass—as in ne largest, 970-pound extinct Malagasy lephant bird—or possibly lack wings alogether—as in the largest, 530-pound exnct New Zealand moa. Similarly, the eaviest Cretaceous tyrannosaurs, includng *Albertosaurus* and the larger, 16,000-ound *Tyrannosaurus rex*, have, relatively peaking, some of the shortest forelimbs f any theropods. This also explains why ne shoulder girdles and forelimbs of *Diayma* and of other large, but unrelated, ightless birds and theropods are outvardly quite similar. These similarities an be interpreted as results of convergent volution, that is, as similar features that ave evolved in unrelated organisms in reponse to similar selective pressures, in nis case, selection for large body size. In nose exceptional theropods with reduced orelimbs whose bodies remained small, pecialized feeding habits seem to be imlied. An example is 70-million-year-old *ononykus* from Mongolia, a turkeyized theropod and putative flightless bird *see* “New Limb on the Avian Family ree,” *Natural History,* September 1993) vith short but powerful front appendages eportedly adapted for ground foraging—ne dinosaurian answer to the kiwi.

In adult flying birds, for example in the ving Muscovy duck, the wing is typically ong in relation to the shoulder girdle, and ne angle between the bones of the shouler girdle (the scapula and coracoid) is usually acute (less than 90 degrees). In embryos of flying birds and in embryos and adults of flightless birds, the wing is often relatively short and the scapulocoracoid angle is commonly obtuse (greater than 90 degrees); in adult *Diatryma,* it approaches 180 degrees. Adult *Diatryma* therefore retained the embryonic condition, an evolutionary process termed neoteny.

Independently of flightless birds, fully bipedal, large theropods, such as *Tyrannosaurus* and *Albertosaurus,* also underwent relative evolutionary reduction of the forelimb while retaining an obtuse angle between the bones of the shoulder girdle. The outwardly similar shoulder girdles and forelimbs of tyrannosaurids and diatrymids can thus be seen as products of convergent evolution, not close phylogenetic relationship, even though convergent forelimbs do not in themselves preclude a relationship between dinosaurs and birds. In the evolutionary history of both groups of strict bipeds, the forearm and hand have tended especially to be progressively and relatively reduced with increasing body size. The upper arm bone (the humerus) has, via selection, retained a more pronounced tendency to lengthen in proportion with the bulk of the body. This continued interdependence, or scaling relationship, between limb length and body mass helps account for the fact that some so-called vestigial limbs, such as the nonflying wings of ostriches and rheas, have remained relatively large and have retained some locomotory and behavioral functions. While ostriches and rheas do not use their forelimbs to fly, they do indeed employ them in display and to steer and balance while running.

Given the demonstrable convergence between large nonflying birds and large theropod dinosaurs, it seems reasonable to ask what the flightless *Diatryma* and other birds are doing in the American Museum's new, phylogenetically arranged Hall of Saurischian Dinosaurs. The question assumes relevance in view of recent characterizations of birds as feathered dinosaurs. The place of birds and dinosaurs in zoological classification is a subject of continuing discussion among ornithologists and paleontologists, and the problem of avian origins cannot be regarded as solved. For now, the hypothesis of bird–dinosaur relationships is magnificently enshrined in the Museum's new dinosaur hall for visitors and scientists to ponder. Here, where awesome giants like *Diatryma* and *Tyrannosaurus* rise up and flail reduced front appendages in what some systematists would consider to be perilous proximity, one may well consider whether birds and theropods are related or whether, as the novelist Flannery O'Connor put it, “Everything that rises must converge.”



The closest living analogue of the extinct giant groundbird Diatryma, *left, may be the four- to seven-pound flightless, grass-eating takahe, right, of New Zealand.*

G. Heilmann, *The Origin of Birds,* London, 1926

Don Hadden; Hedgehog House

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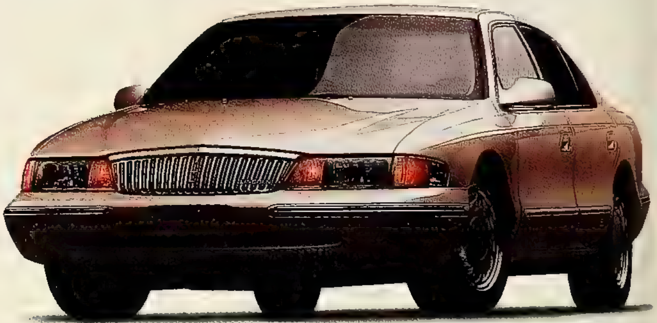

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Significant Others

by Matt Cartmill

We know that anthropomorphism is supposed to be a bad thing, but just what it is is not so clear. The ancient Greeks invented the word *anthropomorphos* (human shaped) to stigmatize the vulgar habit of projecting human faces and feelings onto the immortal gods. Nowadays, people who condemn anthropomorphism worry more about projecting human traits in the opposite direction, downward onto the "lower" animals. Experimental biologists are especially offended by any whiff of anthropomorphism. Anyone who studies biology or psychology learns early on not to report that a lab rat was frightened or curious, but only that it "exhibited a startle reaction" or "displayed investigative behavior." In the psychology lab, all animals are mindless unless proved otherwise.

Other scientists think that a modest amount of anthropomorphism is realistic. Those of us who study human evolution tend to assume that because our closest animal relatives have brains and bodies much like our own, they probably have minds something like ours, and that—as Darwin put it—"there is no fundamental difference between man and the higher mammals in their mental faculties." Evolutionists expect to find continuity among all living things, so they look for rudiments of humanity in other animals. Experimental biologists, who are interested in prediction and control, want to find simple, mechanical explanations for the humanlike behavior of animals. Their ideas about animal minds differ accordingly.

For the past twenty-five years, these two habits of scientific thought have been clashing with each other in the debate over ape "language." Nobody has ever been able to train apes to actually speak, partly because they don't have the necessary fine motor control over the tongue and larynx. Starting in the 1960s, various researchers tried to get around this problem by teaching apes some form of sign language. At first their efforts seemed successful. The apes learned various signs—either the gestures used by the deaf or abstract symbols on keyboards—and used them meaningfully to ask for things, answer questions, and comment on their worlds. We seemed to have finally found a window into the minds of nonhuman animals.

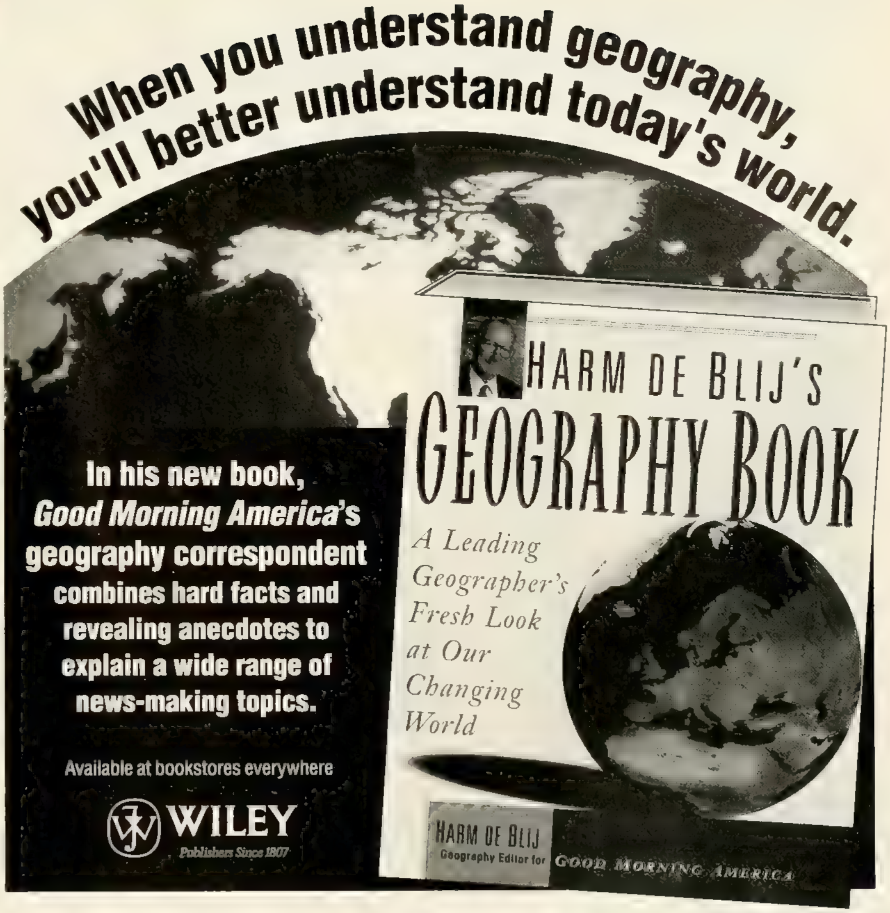
JENNIE, by Douglas Preston. *A Wyatt Book/St. Martin's Press; $21.95; 302 pp., illus.* KANZI: THE APE AT THE BRINK OF THE HUMAN MIND, by Sue Savage-Rumbaugh and Roger Lewin. *John Wiley and Sons, Inc.; $24.95; 299 pp., illus.*

But it didn't take long before skeptics began poking holes in the ape-language studies. Most of the apes' "utterances" were requests, mainly for food. This sort of "instrumental" use of signs is within the reach of many trained animals. Any dog can be taught to bark when he wants a cookie, but that doesn't make "woof" the dog's word for "cookie." It wasn't clear that a chimpanzee's sign for "banana" was anything more than another trick performed for a treat. Worse yet, there was no order or pattern in the apes' signing. A chimpanzee who wanted an apple might sign "apple gimme" or "gimme apple" or "you me apple apple gimme apple eat." The apes' trainers cheerfully interpreted these random-looking strings as language, but more skeptical observers were reminded of a parrot running through its

epertoire of utterances in the fond hope of
:arning a cracker. What was missing in all
he ape-language experiments was evi-
lence of syntax—that is, patterns in the
ırdering of signs that give them different
neanings in different combinations, as in
Fred loves Jane" versus "Jane loves
'red." And without syntax, the skeptics
nsisted, no true language could exist.

These issues are laid out for the general
ublic in two intriguing new books about
igning chimpanzees. One is a piece of fic-
ion, while the other is a scientist's memoir
f twenty-five years of ape-language re-
earch. But they raise similar questions
nd leave the reader thinking similar
houghts.

Jennie, the heroine of Douglas Preston's
ıovel, is a baby chimpanzee born to a
lying female that was brought by an
African hunter into the camp of Hugo
Archibald, a Harvard anthropologist col-
ecting animals for his museum. Hugo de-
ides to take Jennie back to his suburban
ome, where she becomes a strange surro-
ate child. His son, Alex, makes her his
est buddy, but Alex's young sister, Sarah,
rows to hate Jennie as a rival for their fa-
ier's love. Their mother, Lea, appalled at
rst by the disorder that Jennie visits on
ie Archibald home, becomes fiercely
rotective of her when a rival surrogate
ıother appears. The rival mom is Dr. Pam
'rentiss, a hard-nosed primatologist who
tarts teaching Jennie sign language and
nds up secretly adoring her as the daugh-
r she never had. Equally smitten with
ennie is the minister living next door,
vho arranges to give her weekly religious
ıstruction. (Lea relishes this arrangement
ecause it infuriates Prentiss.) Jennie
arns 168 signs from these people and in-
ents 25 more. Syntax remains beyond her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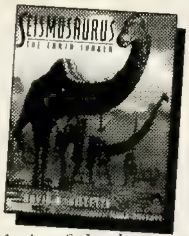

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—*The Atlantic Monthly*

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grasp, but she becomes famous for the other quasi-human things she does.

The story nosedives into tragedy toward the end, when Jennie matures sexually and becomes impossible to control or discipline. Insanely jealous of Alex's girlfriends, Jennie bites off one of his fingers in a fit of rage. The Archibalds can cope no longer, and they let Dr. Prentiss send Jennie off to a Florida retirement home for captive chimps. Jennie (who has never seen another chimpanzee) tries to kill the other apes she meets and has to be locked in a cage, where she grows sick and crazy. Alex, trying to rescue her, is arrested and jailed. Jennie is found mysteriously dead in her cage the next day with her skull bashed in. By the end of the book, just about everybody who was close to Jennie has either become a hermit, gone into therapy, or died.

Jennie is not a cheerful book, but I found it a joy to read. The human characters are engaging and convincing, and their lives are bent out of shape in interesting ways by Jennie's impact. Jennie's death seems genuinely tragic, partly because her religious lessons have given her a dim awareness of death, and we suspect that she has transcended her animal state through suicide.

Preston also deserves praise for his ingenious solution to the problem of writing a serious novel about an animal. The other such books that I've read either make the animals talk (*Black Beauty*) or describe their acts and feelings without letting them utter or think a word (*Tarka the Otter*). Both approaches have drawbacks. Talking animals are unbelievable, but a character who never says or thinks anything is boring. Preston gets around this dilemma by presenting Jennie's story as a string of reminiscences by her human friends. Because these people all speak with utter conviction but differ considerably in their voices and viewpoints, the result has something of the teasing fascination of *Rashomon;* Jennie remains a mysterious chimpanzee-shaped hole in a tangle of human projections, and we can never know the truth about her.

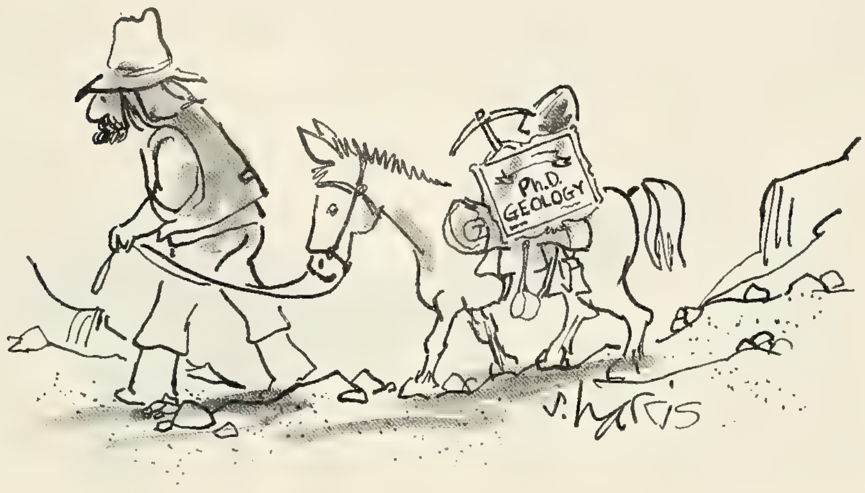
This is a clever narrative device, but I think it works against Preston's obvious desire to blur the boundary between apes and people. Since the human narrators have very different visions of Jennie, the main things we know for sure about her are the points they agree on; namely, that she knows and uses various signs (especially rude ones), screeches a lot, and makes messes. As a result, I was left with the ironic image of an ape having a screaming tantrum—throwing food, tearing up books, and making obscene gestures—while a crowd of wishful-thinking scholars dance around praising her as an unfallen Eve, an abused child, and a noble savage. Seen in this light, the book becomes a cautionary tale about the perils of anthropomorphism. The blurbs on the book's back cover show that it charmed some leading proponents of a semihuman status for chimpanzees, but I think it might be equally relished by skeptics.

The skeptics will have a harder time with *Kanzi*. Ever since Sue Savage-Rumbaugh began studying ape "language" in 1970, she has been sharply aware of the difference between using a sign and meaning something by it. She noted early on that signing chimpanzees wouldn't respond to instrumental signs directed at them, any more than a trained dog would give you a cookie if you barked at it. These animals, she concluded, had no real comprehension of the signs they were using and needed to learn to listen before they could learn to talk.

In 1975, she set out to get two chimpanzees to listen to one another by making them punch signal buttons to "ask" each other for the tools and information they needed to get food out of locked boxes. The apes got the idea almost at once and started swapping food, tools, and keyboard signals back and forth with gusto. Sometimes they would name actions and then perform them—strong evidence for intention and forethought. Sometimes they would assign their own, new meanings to unused buttons on the keyboard—proof of conceptual thinking and creativity. When Savage-Rumbaugh overextended one of these new meanings, the ape repeatedly corrected her—demonstrating that this was a chimpanzee sign, with a chimpanzee concept attached.

In 1982, the researchers discovered that they had a simian prodigy in their colony. Kanzi, the foster son of a somewhat slow-witted female pygmy chimpanzee that had learned only six keyboard signs in two years, turned out to know all the other signs they had tried and failed to teach his mother. He had learned all this stuff on his own, picking up on the right answers by watching his mother give the wrong ones. This sort of spontaneous, unreinforced language learning had been thought uniquely human. Even more surprising, Kanzi had passively learned the meanings of about 150 *spoken* English words. Most amazing of all, he appeared to understand elements of English syntax, reliably distinguishing, say, "Throw the potato at the ball" from "Throw the ball at the potato." He couldn't say any of these things himself, but he could respond correctly to them. Like people—and unlike other signing chimpanzees—Kanzi didn't need to be taught to listen and could listen better than he could talk. To Savage-Rumbaugh and her coauthor, Roger Lewin, all these facts suggest that "apes, like humans, need to be exposed to language during infancy in order to acquire it."

No matter how we raise them, chimpanzees are never going to speak English or read this book. The skeptics will always be able to find reasons for insisting that "language" is something peculiar to our species. If the fortress of syntax falls, they can retreat to passive verbs or compound sentences as the true markers of human uniqueness. But the arresting fact here is



ot that so many language skills are niquely human; it is that speechless aniials have linguistic abilities at all. The act that they do—which is surely no onger in doubt—strengthens the case for iinking that our minds, like our bodies, re largely something we have inherited rom our animal ancestors and share with ur close animal relatives. To many of us, ie skeptics' dread of anthropomorphism ooks more and more like a case of hysterзal blindness.

The authors of *Kanzi* blame a lot of that lindness on the experimental traditions iat we have carried over from physics nd chemistry into comparative psycholgy. In the lab, the only behavior that ounts is *replicable* behavior, in which the nimal responds to the same stimulus in ie same way over and over. Outside the ıb, this sort of stereotyped behavior is alled pathological. If the science of aniial behavior insists that the investigator ıust rigidly control all variables and that nly repetitive behavior can count as data, naturally has to wind up seeing animals s mechanical bundles of programmed reponses. Evidence for something beyond iat—for animals' creativity, intentionaly, or deliberate deception—is going to be necdotal evidence. "By labeling most inзresting observations of animal behavior s anthropomorphic anecdotes," Savageumbaugh and Lewin conclude, "we unvittingly eliminate the need for serious cientific attempts to understand such beavior."

When we move out of the lab, relax ontrol, and let the animals try to make us o what *they* want, we see things in a difзrent light. Whenever a horse nudges us ɔward an empty feed bucket, or a dog truggles to make us notice some danger iat needs our attention, such actions show s that beasts have desires and intentions, nd that they can be creative in trying to ɜll us what they want and prodding us ıto doing it. These homely facts make as onvincing a case for animal intentionality nd creativity as anything the experiienters have managed to come up with in venty years of searching for syntax in ape language." In the last analysis, perhaps ie best reason for thinking that some aniials have minds like ours is simply that iey seem to recognize that we have minds ke theirs.

latt Cartmill is an anthropologist at uke University. His book A View to a eath in the Morning *is a history of ideas bout hunting and human origins.*

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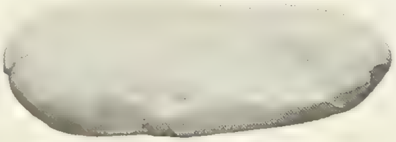

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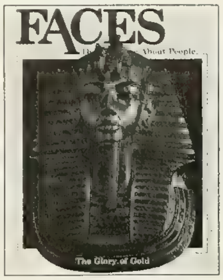

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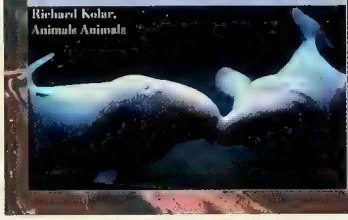

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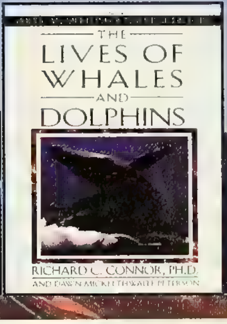

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AT THE AMERICAN MUSEUM OF NATURAL HISTORY

RETURN OF THE DINOSAURS

The Hall of Saurischian Dinosaurs and the Hall of Ornithischian Dinosaurs will open Friday, June 2. Part of a larger renovation of the Museum's fossil halls, which began more than four years ago and will be completed in 1996, the two halls will house the world's most comprehensive exhibition of fossil dinosaur material. Recently discovered fossils will augment well-known specimens in the Museum's collection. Many of the original mounts, like that of *Tyrannosaurus rex,* have been conserved, cleaned, and reassembled to reflect changes in the scientific perspectives on these creatures and their evolution. Highlights of the exhibition include *Apatosaurus* (aka *Brontosaurus*) with a new skull, additional neck bones, and a tail that has been lengthened by nearly twenty feet; a partial "mummy" of a duck-billed dinosaur; a *Velociraptor* specimen; and a horned dinosaur with patches of skin impressions fossilized on the skeleton.

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Recent photographs taken by the Hubble Space Telescope are currently on display at the Planetarium. Photographs of the M87 galaxy and images of strikes made by Comet Shoemaker-Levy 9 are among the highlights of the exhibit. Call (212) 769-5900 for information about all Planetarium events, including the Sky Show, "The Ten Most Asked Questions About the Universe."

PRISON TATTOOS

The distinctive style and symbolism of prisoners' tattoos will be the subject of a talk on Tuesday, June 20, by Chris Brady, of the Idaho State Historical Society. Brady will discuss the significance of tattoos as a visual record of inmates' lives and as indicators of personal status. This program will begin at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for more information.

SPANISH DANCE

Classical, folkloric, and flamenco dances will be performed by the Carlota Santana Spanish Dance Company on Thursday, June 8, at 7:00 P.M. in the Main Auditorium. Call (212) 769-5606 for ticket availability.

NEW YORK CITY FOR THE ARMCHAIR TRAVELER

On Tuesday, June 27, historian Hope Cooke, former queen of Sikkim and author of the recently published *Seeing New York: History Walks for Armchair and Footloose Travelers,* will speak on little-known aspects of New York's social history, architecture, and culture. The program will take place at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for more information.

WEEKEND "EXPEDITION" PROGRAMS

In conjunction with the Museum's 125th anniversary "Expedition" program, special cultural and scientific events will be presented every weekend in June. Included are performances by the Philippine Dance Company on June 3 and 4; a demonstration about evidence of environmental change in tree cores on June 10; Native American animal folk tales related by sto
ryteller Cochise Anderson o
June 18; and a recital by the Th
Music and Dance Society
America on June 25. For a fu
schedule of events, call (21
769-5315.

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relate Tewa Indian myths th
she heard as a child growing u
in San Juan Pueblo's trading po
in New Mexico. Her present
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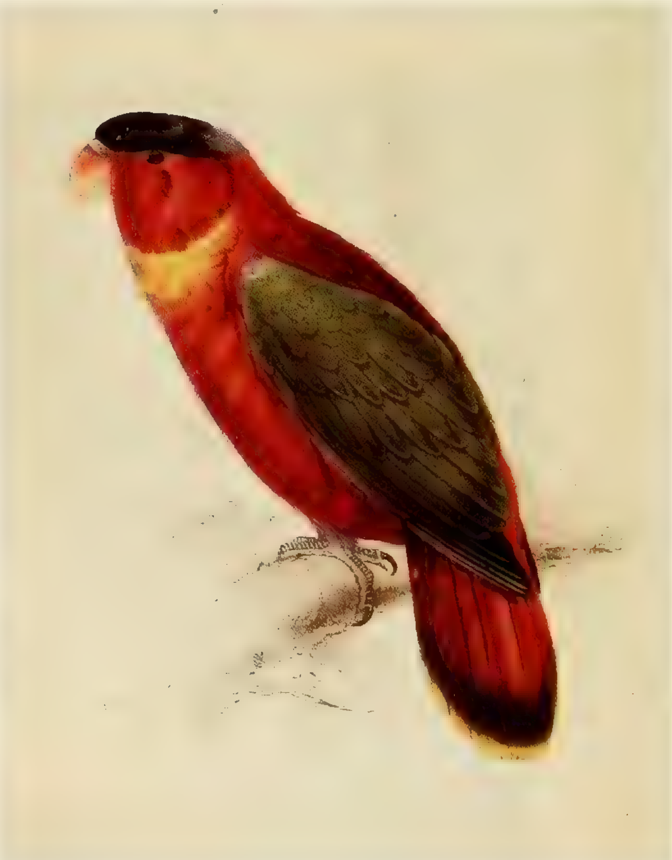

Black-capped lory, painted in 1832 by Edward Lear. Famous for his nonsense verse, Lear was also a zoological artist. A selection of his illustrations is now on display in the exhibition "Art in the Service of Science," in the Museum's library gallery.

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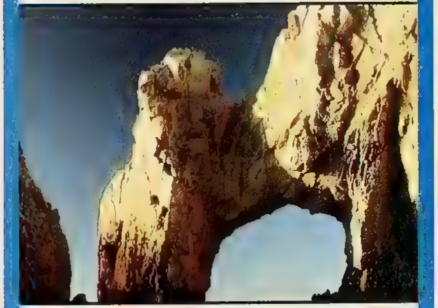

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In-Flight Snack

Shortly after sunrise, a striped morning sphinx moth makes its rounds, sipping nectar from the blossoms of bee balm, a wild mint. Without the benefit of a camera to freeze the motion, casual observers occasionally mistake the insect for a small hummingbird darting from flower to flower. The moth's resemblance to the diminutive bird, however, is merely a case of convergent evolution: both animals independently acquired the ability to hover in midair while drawing sugary liquid from the nectaries of deep-throated flowers. Hummingbirds use their thin, elongated bills to get at their food, while sphinx moths are equipped with long, flexible tongues, which they uncoil to probe a flower's interior. Their flight also distinguishes the moths; they seem unable to match the hummingbirds' ability to zoom away from a flower in reverse.

Sphinx moths (often called hawk moths in Europe) get their name from the larvae's ability to puff up when threatened, giving them a sphinxlike appearance. Almost all of the 123 species found in North America feed at night, but about a dozen can be seen by day. In addition to the moth shown here (*Hyles lineata*), which flies during twilight hours, the clear-winged hummingbird moth (*Hemaris thysbe*) can be seen visiting flowers all day, as can the yellow-and-black-banded bumblebee moth (*Hemaris diffinis*). Unlike the mottled gray-and-brown night-flying moths that rest camouflaged during the day, the diurnal moths are often brightly colored, blurring the somewhat artificial distinction between butterflies and moths.—*R. A.*

Photograph by Joe McDonald

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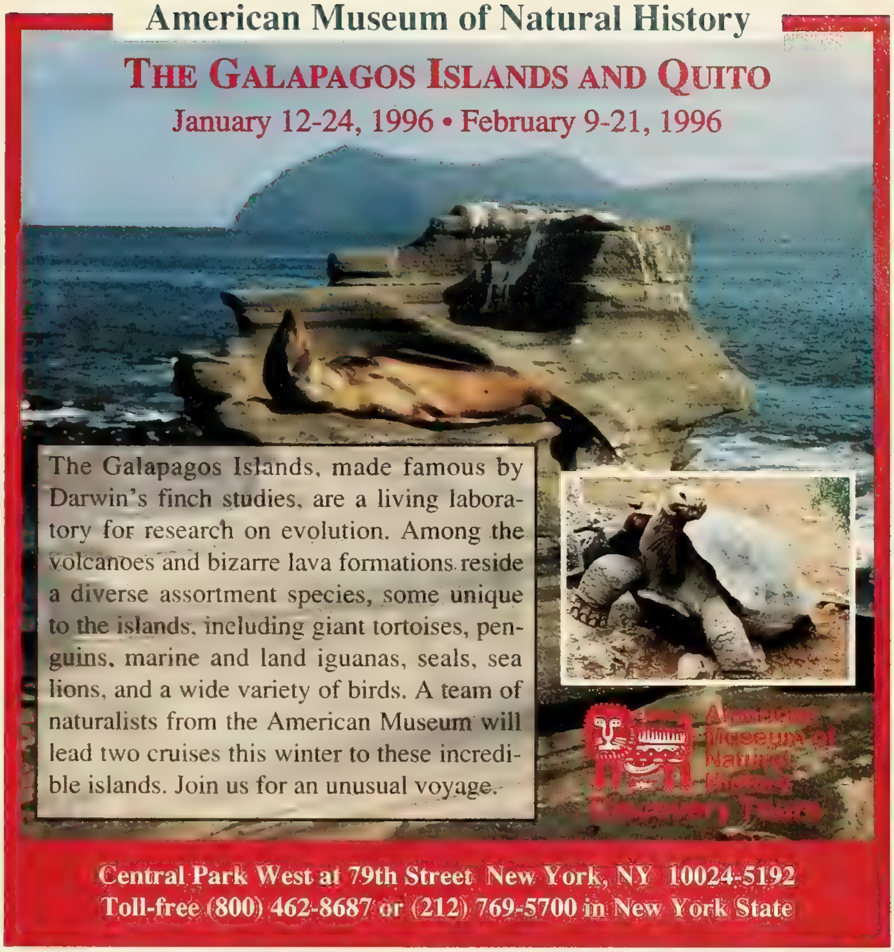
For the past five years, **Eugene S. Gaffney, Lowell Dingus,** and **Miranda K. Smith** (page 33) have channeled their creative and scientific efforts into the American Museum's major renovations of its fossil vertebrate halls. As a curator of the renovation program, Gaffney (center) has helped to structure the exhibitions according to the scientific principle of cladistics. Since 1970, he has been a curator of fossil reptiles in the Museum's Department of Vertebrate Paleontology, where his main research involves the systematics of turtles. He has just completed a project on the earliest (Triassic and Jurassic) turtles and is just beginning another on side-necked turtles. With Mark Norell and Lowell Dingus, Gaffney is the author of *Discovering Dinosaurs* (New York: Knopf, 1995). A vertebrate paleontologist at the Museum, Lowell Dingus is the renovation project director. He received his doctorate from the University of California at Berkeley. When not attending to the countless details of the exhibition, he works on stratigraphic correlation problems involving the K–T boundary (the time of the extinction of most dinosaurs some 65 million years ago) in Montana and in Mongolia. Both Dingus and Smith contributed to the evolutionary exhibition "Life Through Time" at the California Academy of Sciences in San Francisco. Smith, of Ralph Applebaum Associates in New York—designers of the halls—is the content coordinator of the new exhibitions. Smith received her master's degree in paleontology at Berkeley in 1986 and is particularly interested in cladistics as the organizing principle of the new fossil halls. She is also a scientific illustrator and is writing a dinosaur cookbook for children.

"My love of dinosaurs began at the age of five," says **Scott D. Sampson** (page 36). "On the one hand, that makes me the kid who never grew up; on the other, how many people can claim to have a job that is the envy of most six-year-olds?" Sampson, a Canadian, earned his doctorate in zoology from the University of Toronto. He has helped design shows and educational programming for the H. R. MacMillan Planetarium in Vancouver, served as a crew chief at the Museum of the Rockies Field School, and conducted research for the fossil halls at the

Paul C. Sereno (page 30) last wrote or *Natural History* on his dinosaur-hunting expedition to Niger in the Sahara "Dinosaurs and Drifting Continents," anuary 1995). This month he reports on ome of the work he and his team have ndertaken in South America, where fossils of the earliest-known dinosaurs have een uncovered. Sereno became interested in the potential of the Triassic sediments of Argentina's Ischigualasto valley oward the end of his graduate studies at olumbia University and the American Museum. Now an associate professor in he Department of Organismal Biology nd Anatomy at the University of hicago, Sereno spends as much time as ossible in the field. Africa, in particular, till beckons, and he is currently in Morocco, in search of more Cretaceous inosaurs from Africa.

merican Museum. Currently an assisant professor of anatomy at the New ork College of Osteopathic Medicine, of e New York Institute of Technology, ampson spends his summers in the field. e plans to do more work this year in lberta's Dinosaur Provincial Park and in 996 will head even farther north to excaate remains of polar dinosaurs. In addion to his work on horned dinosaurs, ampson is interested in testing hypothees about evolutionary change by inteating phylogeny with ecology and ehavior.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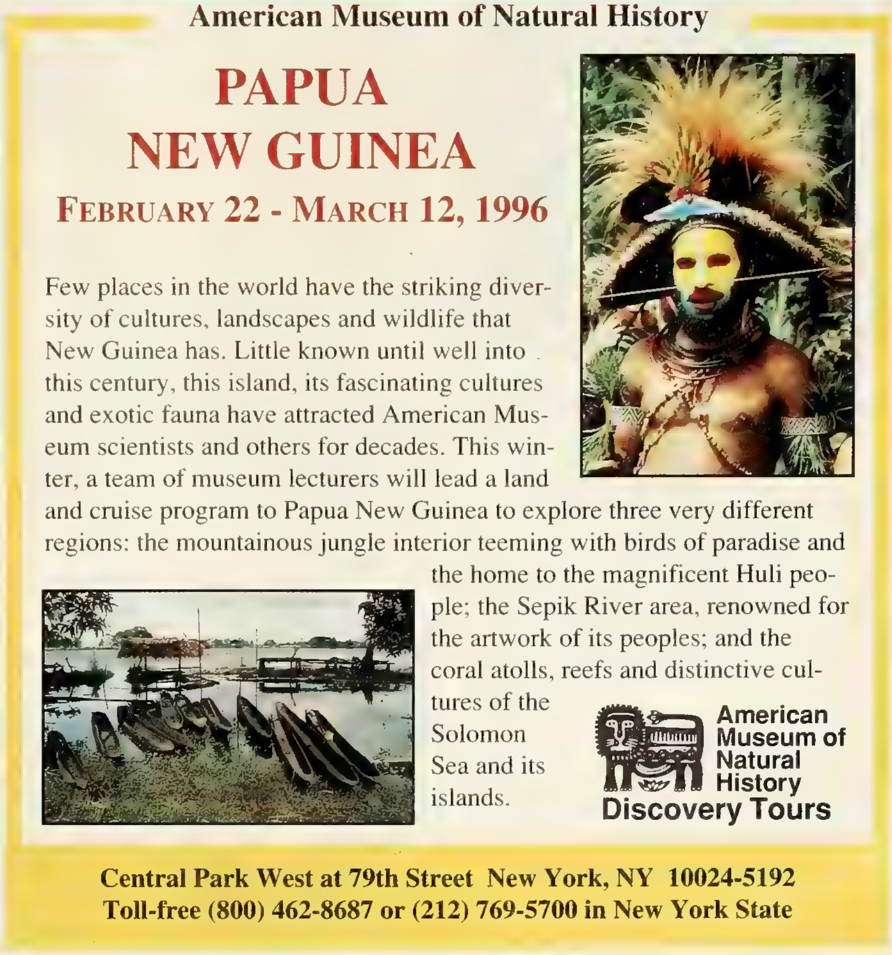
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Few places in the world have the striking diversity of cultures, landscapes and wildlife that New Guinea has. Little known until well into this century, this island, its fascinating cultures and exotic fauna have attracted American Museum scientists and others for decades. This winter, a team of museum lecturers will lead a land and cruise program to Papua New Guinea to explore three very different regions: the mountainous jungle interior teeming with birds of paradise and the home to the magnificent Huli people; the Sepik River area, renowned for the artwork of its peoples; and the coral atolls, reefs and distinctive cultures of the Solomon Sea and its islands.

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The state paleontologist of Utah since 1988, **David D. Gillette** (page 41) does fieldwork all over that state and in New Mexico, although he has also put in time in the field in most continents. He taught at his alma mater, Southern Methodist University in Dallas, Texas, then served as a curator of paleontology at the New Mexico Museum of Natural History from 1983 to 1985. With a dedicated crew, Gillette spent seven years excavating the skeleton—and associated gastroliths—of *Seismosaurus*. His popular account of the discovery and excavation of this beast, *Seismosaurus, The Earth Shaker* (New York: Columbia University Press, 1994), includes descriptions of how high technology can be applied to dinosaur paleontology. Gillette continues to study sauropod evolution and is also involved in research on the evolution of North American Ice Age animals, especially mammoths. When he is not scouring Utah for fossils, Gillette is a volunteer in the Big Brother–Big Sister program and enjoys many adventures with his Little Brother, Heath Besner, age ten, and Heath's twin brother, Brock.

After getting his doctorate in geology from the University of Birmingham, England, and serving as a research associate at Glasgow University in Scotland, **Martin Lockley** (page 46) headed for the American West, where more and more discoveries of fossil tracks and trackways were coming to light in the early 1980s. Now a professor of geology at the University of Colorado at Denver, not far from parts of the "dinosaur freeway," Lockley tracks dinosaurs and other extinct creatures near home and abroad. He has examined and mapped tracks all over the western United States, western Europe, and South Korea; his next destination is central Asia. Fittingly, Lockley's favorite sports are track and field athletics. The author of *Tracking Dinosaurs: A New Look at an Ancient World* (Cambridge: Cambridge University Press, 1991), Lockley has most recently written, with A. P. Hunt, *Dinosaur Tracks and Other Fossil Footprints of the Western USA* (New York: Columbia University Press, 1995).

"Birds have always fascinated me," says **Luis M. Chiappe** (page 52). "I always wanted to understand their origin and first evolutionary steps—in other words, to know how birds came to be like they are today." A research associate at the American Museum, Chiappe earned his doctorate in biological sciences from the Universidad de Buenos Aires in 1992 and started as a research fellow at the American Museum that same year. For the past ten years, he has worked primarily on Mesozoic (age of dinosaurs) birds from Argentina, Mongolia, Spain, and the United States. He is the senior editor of the first technical book on Mesozoic birds, to be published by the University of California Press. His future projects will take him back to previous field sites in Patagonia and the Gobi Desert, as well as to new ones in Africa, where the record of ancient birds has yet to be deciphered.

"I enjoy traveling to deserts around the world looking for fossils, especially small ones," says **James M. Clark** (page 56). Reported by his colleagues to have a sharp eye for finding the tiniest of fossils in the vastest landscapes, Clark has put that search mode to good use in the deserts of Nevada, Yemen, Mexico, and Mongolia. For the past four summers, he has joined the American Museum's expeditions to the Gobi, where he and other team members have discovered the remains of extinct small reptiles and mammals, as well as of dinosaurs. In addition to studying oviraptorids and other dinosaurs from the deserts of central Asia, he specializes in research on the evolution of crocodilians and the origins of birds. Clark earned his doctorate in anatomy

Mark Norell (page 58) is responsible for one of the most remarkable discoveries to have emerged from the American Museum's expeditions to the Gobi Desert—the first embryo of a carnivorous dinosaur (reported by James Clark in this issue). A member of the Museum's field

In her fourth year of college at the University of Durban-Westville in Natal, South Africa, **Anusuya Chinsamy** (page 62) signed up for an optional topic in paleontology and got "hooked." After earning her doctorate from the University of Witwatersrand in Johannesburg, she discovered the field of dinosaur bone microstructure, which encompasses the disciplines she most loves—paleontology, histology, and physiology. Chinsamy, who did postdoctoral work at the University of Pennsylvania, is now a staff scientist at the South African Museum in Cape Town. She plans to continue to study bone microstructure in extinct and living animals and to combine lab research with fieldwork in the Algoa basin of South Africa. Chinsamy has a particular interest in education: "I find talking to

rom the University of Chicago and has
vorked as a postdoctoral fellow at the
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eam for the past four years, Norell has
lso written for *Natural History* on an-
ther denizen of ancient Mongolia, the
nost unusual *Mononykus* ("New Limb on
ne Avian Family Tree," September
993). Norell, who received his doctorate
n zoology from Yale in 1988, is an asso-
iate curator in the American Museum's
epartment of Vertebrate Paleontology.
Ie will return to Mongolia with other
eam members this summer to try to find
nore fossils that shed light on the evolu-
on of reptiles, mammals, and dinosaurs,
ncluding birds. Norell is the author, with
ellow Museum paleontologists Eugene
affney and Lowell Dingus, of
iscovering Dinosaurs (New York:
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A diverse group, duck-billed dinosaurs and their kin have given **David B. Weishampel** (page 64) a rich field for investigations since the mid-1970s, when he began work on the possible function of their sometimes flamboyant hollow crests. Since then, using fossils, phylogeny, and computers, he has delved into the workings of ornithopod teeth and jaws, whose sophistication, back in the Cretaceous, was something new in the annals of herbivory. Weishampel, who received his doctorate in geology from the University of Pennsylvania, is an associate professor of anatomy at the Johns Hopkins University School of Medicine in Baltimore. His latest fieldwork has been in Romania, where he is working on the island biogeography of Europe with Dan Grigorescu of the University of Bucharest. Planned projects include further research on the broad issues of dinosaur diversity and ornithopod phylogeny, as well as more work on the finer points of herbivory, such as chewing and foliage fracture properties and the geometry of dentition. Weishampel is the editor, with Peter Dodson and Halszka Osmólska, of *The Dinosauria* (Berkeley: University of California Press, 1990.)

Allison V. Andors (page 68), a scientific assistant in the American Museum's ornithology department, first became interested in fossil birds as a Princeton undergraduate, when he was shown a drawerful of *Diatryma* bones in the university museum. He spent a subsequent academic year on a grant studying with paleontologist Björn Kurtén in Finland. Andors went on to complete a Ph.D. in geological sciences at Columbia University and wrote his dissertation on giant groundbirds of North America. In recent years, Andors has collaborated in researching the distribution and breeding biology of living birds of Patagonia and the zoogeographic relationships between now-extinct birds of South America and Africa. In addition to fieldwork in South America, he has led or participated in several American Museum-sponsored paleontological expeditions to Wyoming, Colorado, and Washington. "When not studying fossil birds," Andors says, "I greatly enjoy watching living birds, reading, traveling, and spending quality time with my wife, mural painter Rhoda Andors, and my Labrador retriever, Bill."

As a child, **Karen Chin** (page 67) was intrigued by most subjects in natural history, but not particularly by "old dead things" like fossils. Her view changed rapidly when she began working for Jack Horner at the Museum of the Rockies in Bozeman, Montana. This apprenticeship led her to specialize not only in finding clues to past life but also in searching for them in what many people would consider unlikely places—coprolites, or fossil dung. Chin's work includes analyzing dinosaur coprolites and searching for molecular biomarkers in a variety of coprolites. She is now a doctoral candidate in geology at the University of California at Santa Barbara. Chin and entomologist Bruce Gill report on their discovery of dung beetle traces in Cretaceous coprolites in an upcoming issue of the journal *Palaios*.

A native of central Pennsylvania, **Joe McDonald** (page 82) began his career as a wildlife photographer at an early age, taking his first snapshots in the eighth grade. He received both his B.S. in biology and his M.A. in communications from Indiana University, in the western part of his home state. Since then, he has traveled around the world photographing wildlife and has written four books, the latest being *Designing Wildlife Photographs* (Amphoto Publications, 1994). With his wife, Mary Ann, McDonald currently organizes photographic tours of wilderness regions in the United States and abroad. The McDonalds are on the road some thirty weeks out of the year, but they are happiest photographing the wildlife that lives near their home. McDonald spotted the sphinx moth featured in this month's "Natural Moment" while walking through the meadow that has grown up behind his house, where myriad wild creatures, including "almost every local species of snake," have appeared since he moved in five years ago. To capture the moth on film, McDonald rushed into the house to get his Nikon F4 equipped with a 200 mm macro lens.

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NATURAL HISTORY

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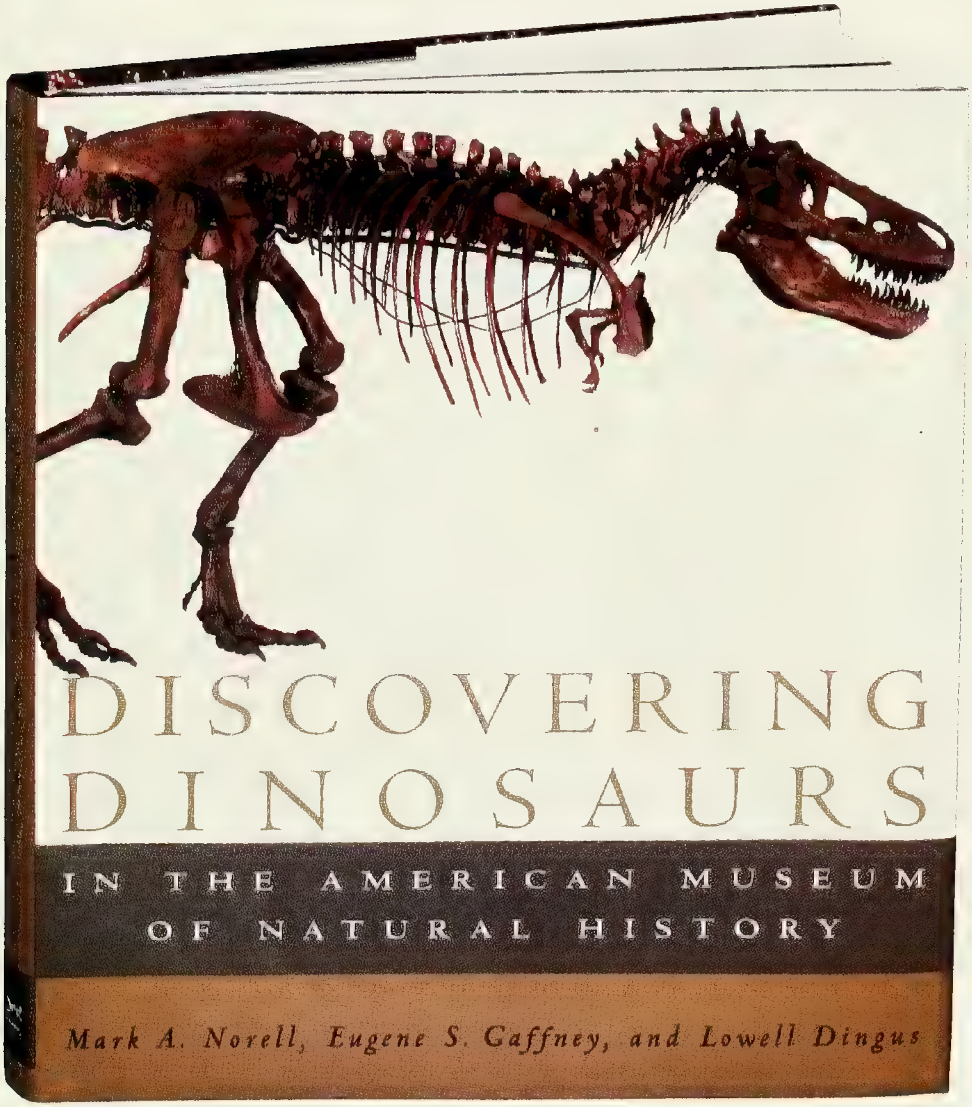
From the American Museum of Natural History— the book that answers your questions about dinosaurs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Up Front

The first detonation of a nuclear device took place fifty years ago, at the secret Trinity site in New Mexico. The second and third followed quickly, over Hiroshima and Nagasaki. I have never visited the targeted cities in Japan, but I have shuffled through the dust and creosote bushes near ground zero at Trinity. I have also explored Bikini Atoll—the site of atomic bomb tests in 1946—prowling through abandoned houses and swimming through the hulks of the blasted ships that lie on the bottom of the lagoon. Such experiences lead me, an archeologist, to reflect on how much humankind's relationship to the natural world has changed since our forebears began wielding tools and weapons.

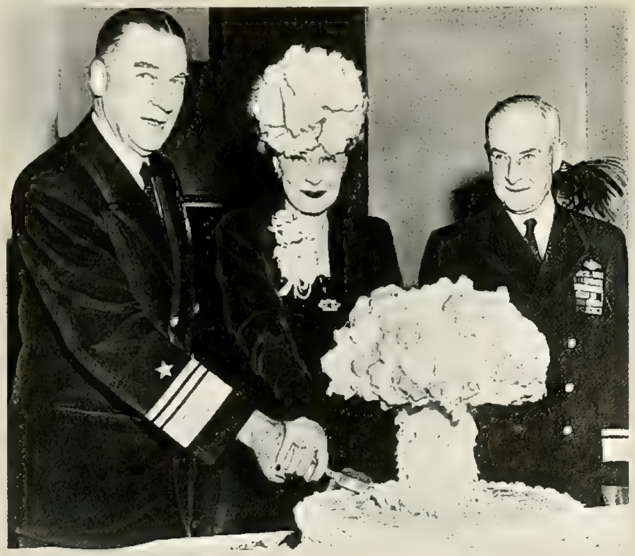
Daniel J. Lenihan's article, **Ground Zero Revisited,** *appears on page 42 of this issue.*

I can see one of our ancestors, perhaps desperately trapped, sticking a tree branch under a heavy rock and levering it away from his cave entrance. The lever wonderfully concentrates his muscular efforts. Sometime later, a band of early humans levers a similar rock off a steep slope, hoping to crush an approaching enemy. Unexpectedly, one rock strikes another in a primitive chain reaction, and the foe is buried in a landslide. A giddy sense of power overwhelms the perpetrators, who quickly adapt the technique to hunt large herbivores.

The ancient landslide that I have imagined was one of the milestones of human history. It tapped the gravitational forces latent in a mountain. A prideful sense of mastery over the natural world evolved as humans harnessed other external sources of power—animals to pull plows, wind and water to grind grain, steam to drive ever larger turbines. But this process has not been without destructive social and environmental consequences. The manipulation of increasingly sophisticated tree branches has led humans to forget that they are part of the nature they seek to control.

On July 16, 1945, humankind passed a new milestone. Atoms, once considered indivisible by definition, were split in an explosive chain reaction, more impressive than any caused by a rock tumbling down a hillside. While the accomplishment gave cause for celebration, it also provoked concern. We had learned to convert matter to energy—the very thought was a revelation. But could we avoid annihilating ourselves in a sudden conflagration or poisoning the world with hazardous residues?

A book of some consequence to human history notes that "he that troubleth his own house shall inherit the wind" (Prov. 11:29). Humans in the millennia to come will redefine their relationship to nature in many ways, but since Trinity the stakes have become increasingly high. Nature, and we as part of nature, are at risk. The explosion in the New Mexico desert is said to have created its own meteorological microenvironment. Lightning and gales heralded the arrival of the new age. Let us hope our inheritance will be one of light and not of wind.—*Daniel J. Lenihan*



In November 1946, Admiral and Mrs. W. H. P. Blandy and Rear Admiral F. J. Lowry celebrated the successful testing of atomic bombs earlier that year at Bikini Atoll.

Pictorial Histories

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COVER: As this young Asian elephant outgrows its need for milk, it may develop a taste for the crops growing in farmers' fields. Story on page 52. *Photograph by William Thompson.*

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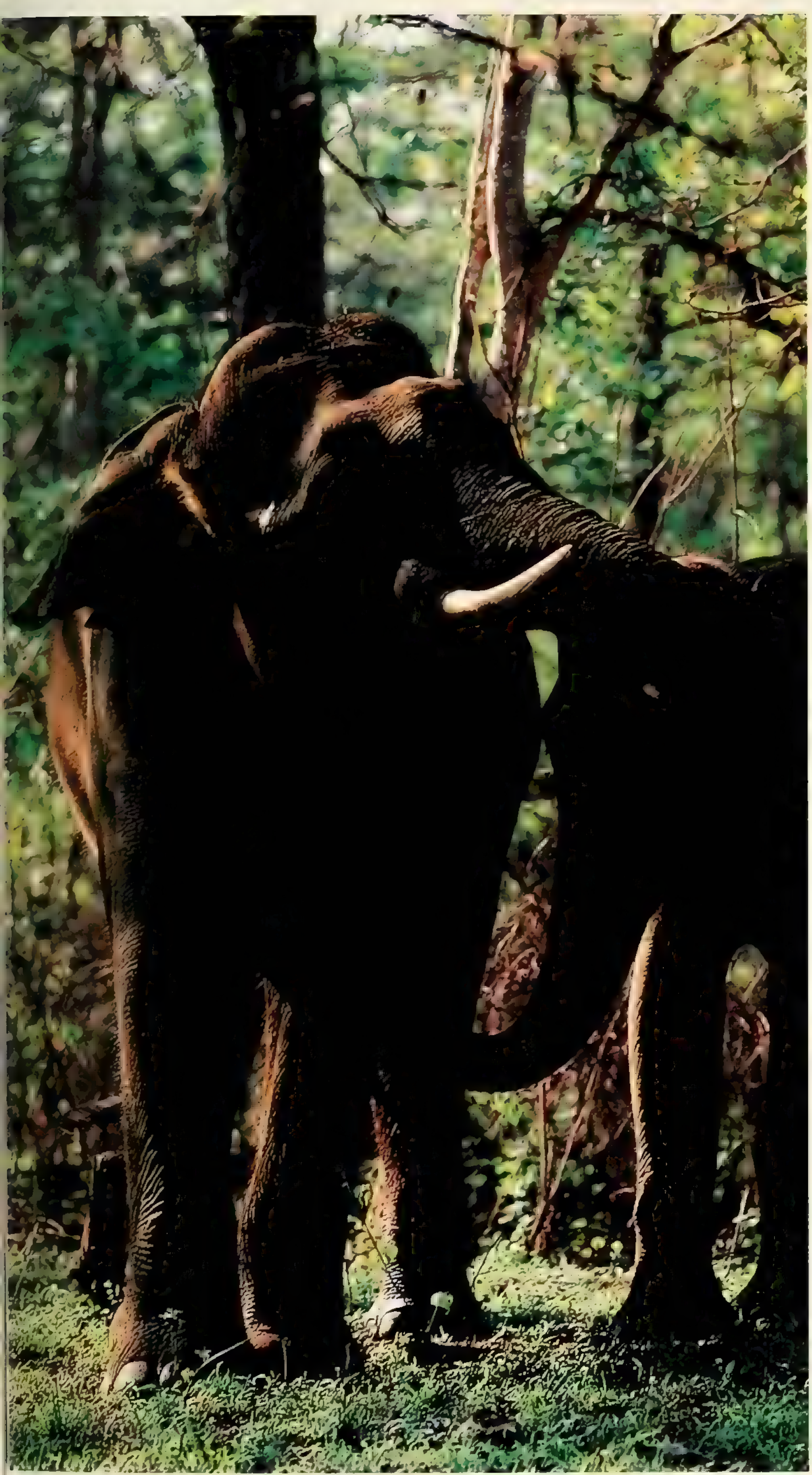

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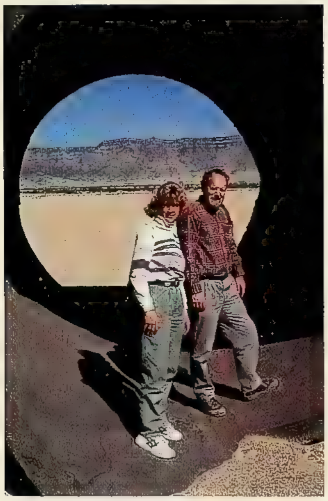
AUTHORS

While growing up in the Pacific Northwest, **Gregory C. Jensen** (page 26) developed an interest in marine biology and a particular fascination with crabs and shrimps. He first noticed the zonation patterns of porcelain crabs while preparing for an eighth grade science fair; years later, when he began attending graduate school, he says "there was never the slightest doubt about what my project would be." Since completing his doctoral dissertation, he has taught crustacean biology at the University of Washington School of Fisheries, and ichthyology at the Shannon Point Marine Center of Western Washington University. He enjoys hiking, scuba diving, and photography, and since he began combining the latter two interests, has found it increasingly difficult to enter the water without a camera. The past two years were particularly enjoyable because he had a "legitimate excuse" to explore and dive, from British Columbia to Mexico, while shooting pictures for his book *Pacific Coast Crabs and Shrimps* (Monterey: Sea Challengers, 1995), the first color identification guide to West Coast crustaceans.

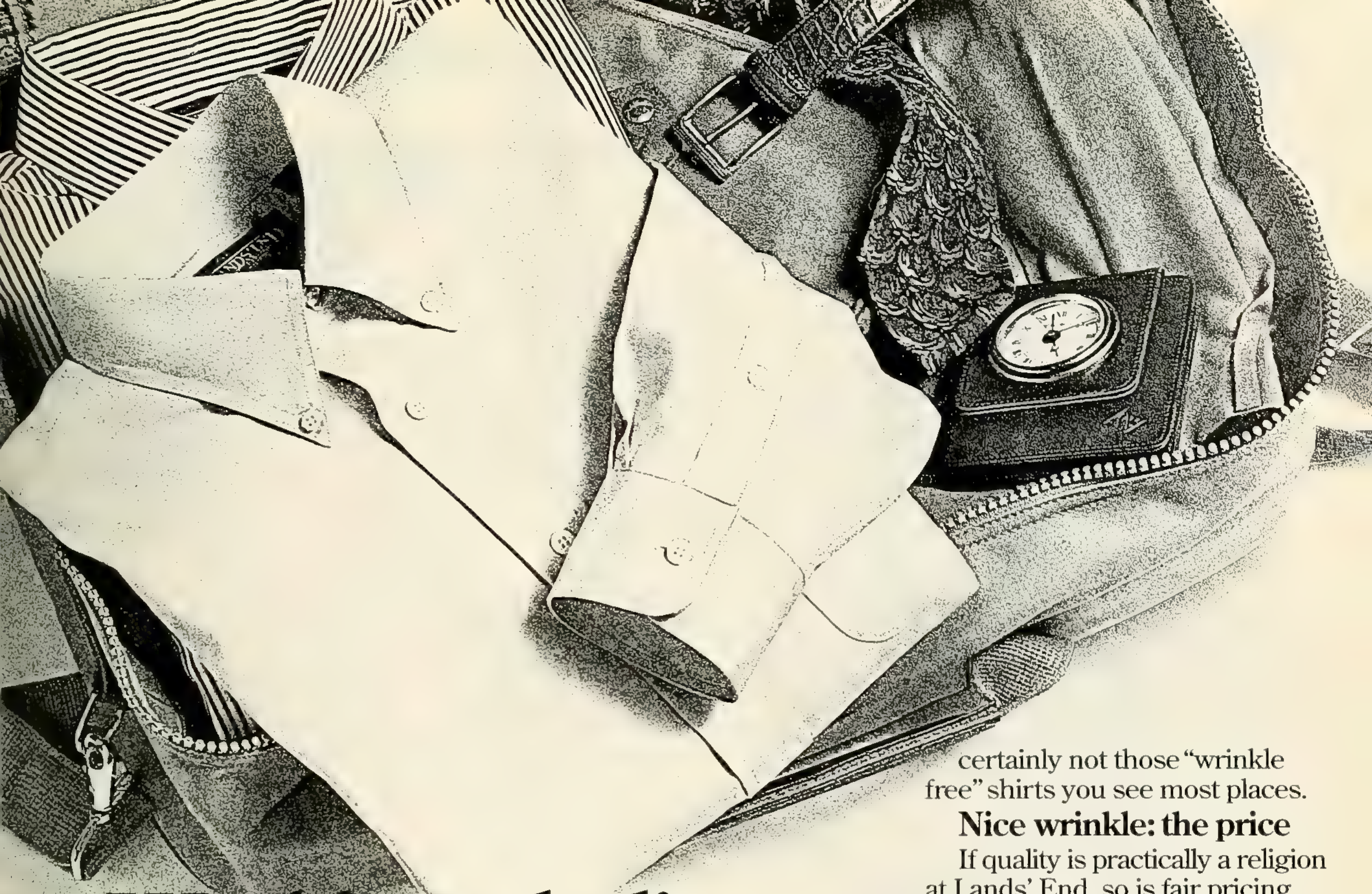


A resident of Sante Fe, New Mexico, for the past twenty years, **Daniel J. Lenihan** (page 42) can see the lights of Los Alamos—birthplace of the atomic bomb—from his bedroom window. Head of the National Park Service's underwater archeology program, Lenihan (shown here with his wife, Barbara) was assisted in his research for his article by archivist-historian Roger Meade. Those curious about another weapon mentioned by Lenihan may want to read *Bat Bomb,* by Jack Couffer (Austin: University of Texas Press, 1992).

On the banks of the Noatak River in Alaska, **Bernd Heinrich** (page 32) stopped to photograph a nest of arctic terns. Upset by the intrusion, the parents repeatedly divebombed him while he captured the eggs on film. A frequent contributor to *Natural History,* Heinrich is a professor of zoology at the University of Vermont, who spends most of his spare time at his cabin in the Maine woods. Occasionally, he ventures farther afield to study a particular interest. His passion for finding hidden bird nests, for example, inspired him to try his luck searching for them on the Alaskan tundra. Although best known for his research on thermoregulation in bees and other insects, Heinrich is inveterately eclectic. Most recently, he has been working on the calling behavior of wood frogs, and the cooperative behavior of ravens searching for food.

An Oregon native, **Chris Johns** (page 78) gives his current home address as the Blue Ridge Mountains near Shenandoah National Park. Known for his wildlife photography, Johns's latest assignment has taken him to Africa, but he took his photograph of the mother alligator and her progeny in the Florida Everglades. "The more I learned about alligators," he says, "the more I appreciated them and thought they had been maligned. My pictures of their kinder, gentler side should help to contradict the bad reputation they have gotten." How did Johns get the shot? "I used a Nikon F4, equipped with a standard 400 mm lens—and the aid of an excellent biologist." Somehow, he also manages to squeeze in "raising children and horses, and that's about all I have time for."

Born and raised in Madras India, **Raman Sukumar** (pa 52) says he was the "usual city-bred child interested in games," more fond of books than animals. In high school however, his "eyes opened t the profound beauty of livin creatures." For the next seve years, he spent most of his weekends in Guindy Nation Park, a seminatural park within Madras's city limits. Sukumar saw—or may have seen—his first wild elephant during a class trip to a sanctuary in Tamil Nadu. To this day, he is not sure wheth what he saw through a patchwork of light and shad was an elephant or a rock, b he *is* sure—after a decade o field experience with sometimes capricious elephants— that it is always better to mistake a rock for an elepha than an elephant for a rock. Currently an assistant professor of ecology at the Indian Institute of Science i Bangalore, Sukumar is also deputy chairman of the Asi Elephant Specialist Group o the IUCN (World Conservation Union) and head of the Asian Elephant Conservatio Centre. His most recent boo is *Elephant Days and Night Ten Years with the Indian Elephant* (New Delhi: Oxfo University Press, 1994).



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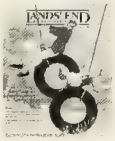

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Spin Doctoring Darwin

Ousted from our cherished place in the center of the universe, we're still in denial

by Stephen Jay Gould

In a wonderfully wise and frequently cited statement, Sigmund Freud identified the common component of all major scientific revolutions: "Humanity has . . . had to endure . . . great outrages upon its naïve self-love." In other words, great revolutions smash pedestals—the previous props for our cosmic arrogance. Freud then identified the two most significant fracturings. First, the cosmological shift from a geocentric to a heliocentric universe: "when [humanity] realized that our earth was not the center of the universe, but only a speck in a world-system of a magnitude hardly conceivable." Second, the Darwinian discovery of evolution, which "robbed man of his particular privilege of having been specially created, and relegated him to descent from the animal world." Freud then hinted that the discovery and elucidation of the unconscious, in large part his own work, might smash a third pedestal in setting aside our convictions about mental rationality.

This statement suggests a criterion for judging the completion of scientific revolutions—namely, pedestal smashing itself. Revolutions are not consummated when people accept the physical reconstruction of the universe thus implied, but when they grasp the meaning of this reconstruction for the demotion of human status in the cosmos. The two phenomena—realignment of the physical universe and reassessment of human status—are truly distinct, a separation best understood by invoking an old mental strategy that has received a striking new name in contemporary culture: spin doctoring.

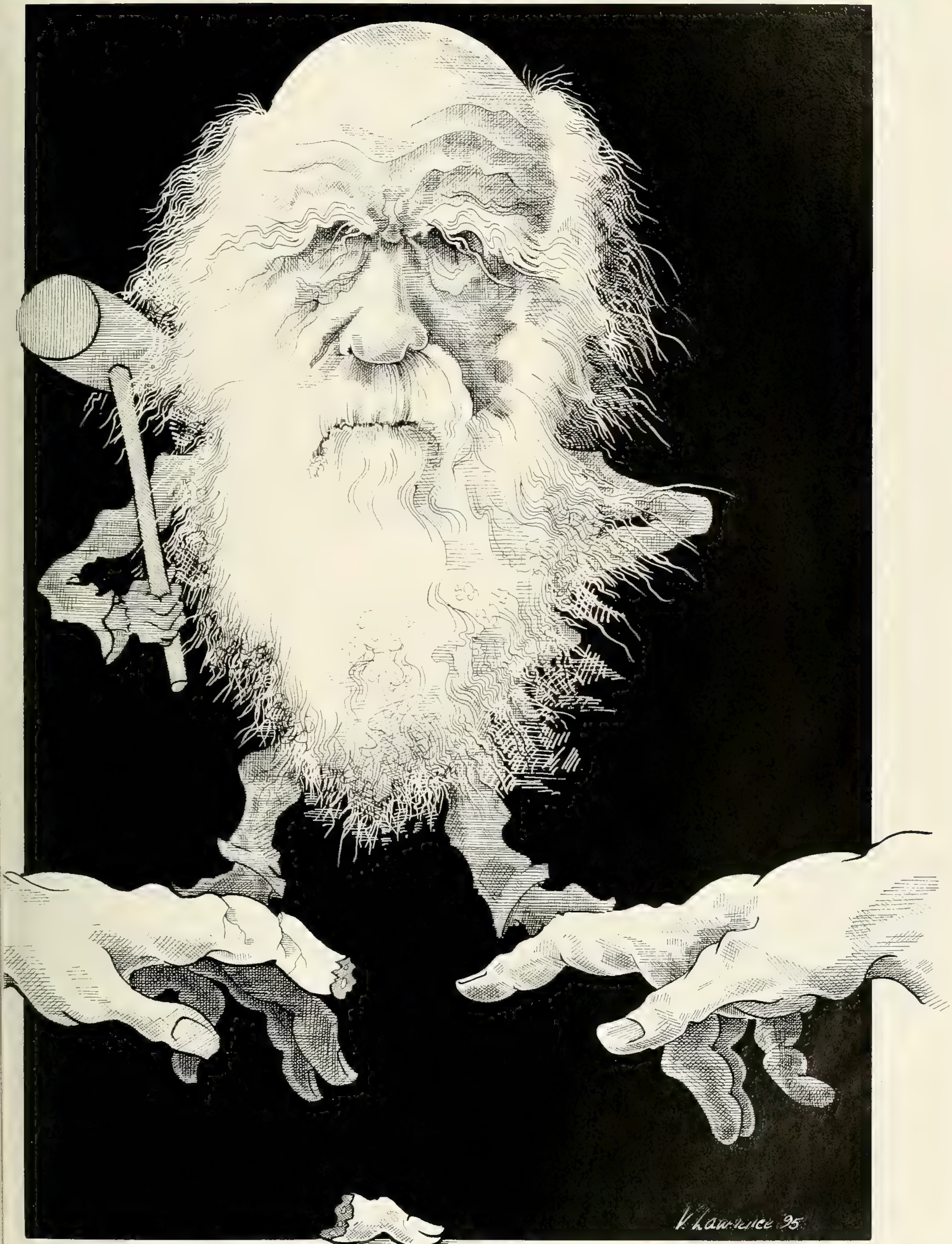
In spin doctoring, an art practiced best by politicians from time immemorial, one accepts a sorry fact, but provides an interpretation based entirely on the silver lining said to accompany all dark clouds. For example, Dr. Pangloss of Voltaire's *Candide,* surely the greatest spin doctor in all Western literature, stated that syphilis, inadvertently transmitted from the New World to Europe, might be unpleasant but that, on balance, all must be for the best because the Americas had also provided such wonderful products as chocolate.

We may say, I think, that Freud's first revolution is complete in his pedestal-smashing sense. All thinking people accept that we live on a peripheral hunk of rock on the edge of one galaxy among gezillions—and no one seems enveloped by cosmic angst, or despairing about the meaning of human life, on these grounds. (Perhaps we have come to terms through the passage of centuries, for the new cosmology did not always seem so unthreatening, and we have not forgotten Galileo's torment. Many early versions of heliocentrism retained the pedestal by placing our own personal star, the sun, in the center of a limited universe.)

But having spent a professional lifetime explicating and defending evolution in both public and technical fora, I feel certain that Freud's second revolution has not been able to surmount a mental roadblock. Evolution still floats in the limbo of our unwillingness to face the implications of Darwinism for the cosmic estate of *Homo sapiens*. Physical reconstruction, the first step in a Freudian revolution, has been accomplished: All thinking people accept the biological fact of our "descent from the animal world." But the second stage, mental accommodation toward pedestal smashing, has scarcely begun. Public perception of evolution has been so spin doctored that we have managed to retain an interpretation of human importance scarcely different, in many crucial ways, from the exalted state we occupied as the supposed products of direct creation in God's image. (Note that I am not even discussing the sociologically significant fact that millions of Americans, but no large numbers in any other Western nation, don't accept evolution at all, and continue to espouse the literal reading of Genesis for a creation of all life in a few days of twenty-four hours. That some people cannot even take the first Freudian step only emphasizes the particular fear and reluctance that this revolution raises in us.)

It takes no great philosophical or cultural acumen to recognize why the Darwinian revolution has been most difficult to accept, and therefore remains least complete in the Freudian sense. I don't think that any other ideological revolution in the history of science has ever so strongly or directly impacted our view of our own meaning and purpose. (Some scientific revolutions, though equally portentous and revisionary in their physical reconstruction, just don't pack as much oomph for the human soul. For example, plate tectonics has thoroughly changed our view of the earth's history and dynamics, but few people have staked the meaning of their lives upon the issue of whether or not Europe and America were once physically connected, and whether or not continents reside within thin plates floating over the earth's surface as new sea floor arises at oceanic ridges.)

Stephen Jay Gould, Frederick P. Rose Honorary Curator in Invertebrates at the American Museum of Natural History, teaches biology, geology, and the history of science at Harvard University.


V. Lawrence '95

I like to summarize what I regard as the pedestal-smashing messages of Darwin's revolution in the following statement, which might be chanted a few times a day, like a Hare Krishna mantra, to force penetration into the soul: Humans are not the end result of predictable evolutionary progress, but rather a fortuitous cosmic afterthought, a tiny little twig on the enormously arborescent bush of life, which if replanted from seed, would almost surely not grow this twig again or perhaps any twig with any property that we would care to call consciousness.

All the classic forms of evolutionary spin doctoring are designed to avoid the radical and unwanted consequences of this mantra. Spin doctoring centers on two different subjects: the *process* of evolution as a theory and mechanism; and the *pathway* of evolution as a description of life's history. Spin doctoring for the process tries to depict evolution as inherently progressive and as working toward some "higher" good in acting "for" the benefit of such groups as species or communities (not just for advantages of individual organisms), thereby producing such desired ends as harmonious ecosystems and well-designed organisms. Spin doctoring for the pathway reads the history of life as continuous flux with sensible directionality toward more complex and more brainy beings, thereby allowing us to view the late evolution of *Homo sapiens* as the highest stage, so far realized, of this predictable progress.

How best can we illustrate that spin doctoring has had its pervasive and baleful effect, and that public understanding of evolution lies immured in biases that prevent the completion of Darwin's revolution in Freud's crucial sense of pedestal smashing? Well, I grew up in New York City, and I remain a quintessentially partisan New Yorker. I still root for the Yankees after twenty-five years in Boston, and my mental map of the United States matches the celebrated Steinberg *New Yorker* cover, with Fifth Avenue essentially dividing the nation and the Hudson River near the Nevada-California border. The United States is too diverse to have a canonical media source for identifying the pulse of an educated culture—as the BBC might do in Britain, or *l'Osservatore Romano* in the Vatican. But grant to this parochial New Yorker that the *New York Times* comes as close to such a status as any American publication.

I therefore suggest that a compendium of commentary from the *Times* might give us some insight into the spin doctoring of Darwin's revolution. I have been struck by three items that appeared in the *New York Times* during the past year, for they represent primary components of the spin-doctored view, yet all are stated with such assurance that evolution *must* have this meaning. I therefore found them, in their collectivity, particularly compelling as an illustration of our deep miring in the spin-doctored view of evolution as sensible and predictable progress, continuously moving toward desired ends by working for the good of groups and communities.

1. *Evolution for the collective good.* On June 6, 1944, the Allied armies launched a great attack that, without cynicism, may be regarded as one of history's finest efforts for global human good. On the fiftieth anniversary of D-Day, June 6, 1994, the *New York Times* lauded the invasion in many front-page articles, and reprinted both General Eisenhower's announcement of the landings, and their own editorial of praise from June 7, 1944. On the same day, the letters column of the *Times* printed this more general commentary on working for the collective good—in response to an earlier article in the Tuesday Science Times section that asked how sexual reproduction might benefit the evolutionary success of individuals.

> The following statement might be chanted a few times a day, like a Hare Krishna mantra, to force penetration into the soul: Humans are not the end result of predictable evolutionary progress, but rather a fortuitous cosmic afterthought, a tiny little twig on the enormously arborescent bush of life.

EVOLUTION BENEFITS SPECIES AS A WHOLE

To the Editor:

The question why sexual reproduction has evolved, should be asked not from the standpoint of individuals . . . but from the standpoint of the species itself. While sexual reproduction continually introduces mutations that can damage individuals of the species, the advantages of this continual introduction of new genetic material into the gene pool is an evolutionary plus for that species. . . . You miss the point. Evolution is not about a good deal for individual females or individual males, but about a good deal for the species.

I am sorry, but the writer has missed the point. Darwin's central theory of natural selection is about advantages ("good deals" if you will) that accrue to individuals, explicitly not to species. In fact, this counterintuitive proposal—that individual bodies, not "higher" groups like species, act as units and targets of natural selection—lies at the heart of Darwin's radicalism, and explains a large part of our difficulty in grasping and owning his powerful idea. Natural selection may lead to benefits for species, but these "higher" advantages can only arise as sequelae, or side consequences, of natural selection's causal mechanism: differential reproductive success *of individuals*.

Warm and fuzzy ideas about direct action for the good of species represent a classical form of spin doctoring that has precluded proper understanding of natural selection for more than a century. If evolution worked explicitly for species, then we could soften the blow of Darwin's radicalism. The transition from God's overt beneficence *toward* species to evolution's direct operation *on* species permits a soft landing in transferring allegiance from creationism to evolution—for the central focus on "higher" good as raison d'être remains unchanged.

But Darwin's real theory of natural selection is uncompromising in kicking this prop away. Natural selection is a theory of ultimate individualism. Darwin's mechanism works through the differential reproductive success of individuals who, by fortuitous possession of features rendering them more successful in changing local environments, leave more surviving offspring. Benefits accrue thereby to species in the same paradoxical and indirect sense that Adam Smith's economic theory o laissez faire may lead to an ordered economy by freeing individuals to struggle fo personal profit alone—no accident i overlap, because Darwin partly derive his theory of natural selection as a creative intellectual transfer from Smith's ideas.

If we free individual businesses to ac for their own benefit, Smith argues, ther the most efficient firms both drive out inompetent competitors and balance each ther to provide an orderly economy. But uch order only arises as a side conseuence, through the action of an "invisible and" in Smith's unforgettable phrase; all irect causality resides in the struggle mong individuals. Similarly, in Darwin's vorld, natural selection acts only for the enefit of individuals in reproductive sucess (firms in profit, by analogy to Smith); vell-designed organisms and balanced cosystems are side consequences.

We can say all we want about the eauty and radicalism of Darwin's central otion, but how do we know that it is true? Iow can we tell that nature is Darwinian, ather than shaped by some other set of volutionary forces?

A convincing set of proofs lies around is, although this simple and powerful oint is rarely articulated in popular writng and therefore remains largely unappreiated. We begin with something of a paralox. The proof of Darwinian nature does ot reside in the best and classic cases of rganic design for optimal biomechanical unction: the aerodynamic perfection of he bird's wing or the hydrodynamic shapng of a fish's body. Darwin's natural seection, working for the reproductive sucess of individuals, might build such xcellence in design, but another kind of volutionary force that worked for the ood of species might yield the same reult. Excellent wings are both good for pecies and good for individual birds. To how that nature is Darwinian we need a et of phenomena that can only be built by orces working for the benefit of individuls, and not for species.

Such phenomena exist in abundance: rgans and devices that aid individuals in exual combat for mates and matings gainst other individuals of the same speies. Such organs cannot be beneficial for pecies, since they only aid individuals in truggle against others of the same species nd cannot aid the species in competition gainst other species. Moreover, these orans are often elaborate and devilishly lever; they represent enormous "investients" of evolutionary energy, not mere rills. Much of evolution's causal effort iust therefore be devoted to building such rgans for individual benefit.

The peacock's tail represents a classic ase. This gaudy and brilliant, but cumberome, structure does the bird no good in a iomechanical sense (and probably acts as positive disadvantage in this regard). But eacocks use their showy tail to compete vith other peacocks for the attention of the peahen in the essential Darwinian activity of passing more genes along to future generations. Showier tails help individual males compete with other males; they do not benefit the species. In fact, fancy tails probably injure the species' prospects for extended geological longevity—and can therefore only arise if evolution works for advantages of individuals.

But even this classic case is indirect, for the tail doesn't raise reproductive success by itself, but only by impressing females or intimidating other males. A host of more direct adaptations work explicitly for individuals in the reproductive act itself. For example, males may hold on to females for weeks or months, thus assuring that no other sperm but their own can fertilize the eggs. (This odd phenomenon, called amplexus in frogs, does the species no good, but surely boosts the reproductive success of amplexing males.)

The ever diverse world of insects yields thousands of stunning examples (*see* William G. Eberhard's remarkable book *Sexual Selection and Animal Genitalia,* and his article "Runaway Sexual Selection," *Natural History,* December 1987, for details). Males of many species, for example, will reach into the female's vulva and pull out the sperm from any previous matings before depositing their own. Others, after mating, secrete a rocky substance that plugs the female genitalia, blocking copulation with any other male—nature's chastity belt after the fact. These examples of "sperm competition" (as professionals label the subject) can only evolve if natural selection works for advantages of individuals, not of species.

> We can say all we want about the beauty and radicalism of Darwin's central notion, but how do we know that it is true? How can we tell that nature is Darwinian, rather than shaped by some other set of evolutionary forces?

2. *Sensible directionality.* Another letter to the *Times* (January 8, 1995), again commenting upon a previous report from the Science Times section, subtly illustrates a major theme in spin doctoring the pathway of evolution (rather than the process). The correspondent objects to a sentence from an article upholding the theory that dinosaurs disappeared in a cosmic catastrophe triggered by the impact of a large extraterrestrial body:

> DINOSAURS AND DESTINY
>
> To the Editor:
>
> In a Jan. 3 Science Times article you report on a theory that dinosaurs died out after an asteroid hit sulfur-rich rock in what is now the Yucatán Peninsula of Mexico, producing a haze of sulfuric acid that blocked sunlight for decades. Had the rock not been rich in sulfur, you say, "the dinosaurs might well have survived the impact, thereby changing the course of evolution."
>
> Actually, it was the demise of the dinosaurs that changed the course of evolution. Had the dinosaurs not been wiped out, evolution would have continued on the same path it had been following for at least 150 million years.

While I will not defend the *Times*'s fuzzy language about "the course of evolution," the writer of the letter labors under the false impression that life's history follows a definite path, and that catastrophic episodes can only be read as disrupters of sensible continuity. I see nothing amiss in what the *Times* wrote on January 3. If the impact hadn't occurred, dinosaurs would probably have survived and evolution would then have proceeded differently from the pathway actually followed during the past 65 million years (an alternative route, I hasten to add, that would almost surely have kept mammals as small creatures in the interstices of a dinosaurian world, thus preventing the origin of a peculiar group of large mammals with consciousness and the eventual invention of the *New York Times*).

The error lies in the assumption that evolution, if not disrupted somehow, follows a path that will sensibly continue into an indefinite future. But no such pathway exists. The course of evolution is only the summation of its fortuitous contingencies, not a pathway with predictable directions. What is the supposed pathway that evolution had followed for 150 million years before the disruption at the end of the Cretaceous? For starters, this 150-million-year interval included a mass extinction just as intense (and perhaps just as catastrophically triggered) as the later event

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Why Is a Cow like a Pyramid?

Cattle domestication on different continents raises basic questions about the role of rare geniuses in human inventiveness

by Jared Diamond

How many times in history did people "invent" pyramids? Think of Mexico's Pyramids of the Sun and the Moon at Teotihuacan or of other pyramids built by American Indians centuries before Columbus's arrival. The resemblance of the American structures to the earlier pyramids of Egypt is so obvious that we call them by the same name. Does this suggest that Egyptians reached the New World in ancient times and taught Mexicans the art of pyramid construction?

Many similar parallels exist between ancient Old World and New World civilizations. Do they also imply diffusion of inventions between the hemispheres? Author Thor Heyerdahl (and many others) have attributed such parallels to transatlantic contacts between American Indians and such seafaring Old World peoples as Egyptians and Phoenicians.

But there are doubters who reason as follows: Suppose you were an ancient emperor who wished to build the largest and highest structure ever seen in order to advertise your power, mobilize your work force, or unify your empire. In ancien times, the tallest building that you coul have built would have been a pyramid American Indians were as capable of figuring that out as were Egyptians. Indeed most scholars now think that Egyptian an Mexican pyramids were "invented" independently, mainly because the structure had differing functions (tombs in Egypt temple bases in Mexico) and were built o different materials.

Such debates about the relative roles o independent invention and diffusion po

Humped cattle, Ahmedabad, India

Dilip Mehta; Contact Press Images

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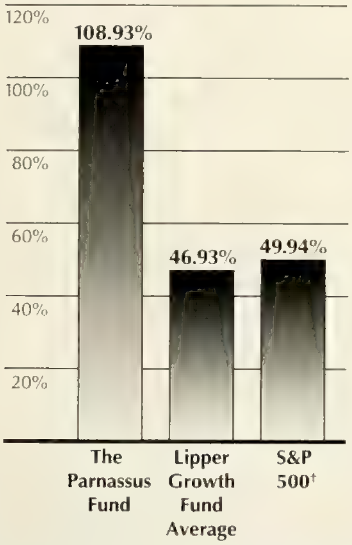

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up again and again among historians, archeologists, and anthropologists. Both capabilities are facts of human nature. On the one hand, humans are inventive. If person *A* thinks of a new idea or invention in Boston on Wednesday, then person *B* could think of it in Dar es Salaam on Thursday. Independent brainstorms happen all the time. But humans also spread and receive ideas. Whenever people travel or emigrate, they bring things and ideas with them, and other people are always on the lookout for new things and ideas.

At scholarly meetings, the arguments rage ad nauseam. Some scholars like inventionist interpretations; others prefer diffusionist ones. The debate quickly becomes polarized because one's answer to it reflects one's whole Weltanschauung and one's view about the role of rare geniuses.

Some recent discoveries, however, may actually have succeeded in resolving one such historical debate: the origins of domestic cattle. The domestication of cattle was one of the most important events in human history, far more important than the construction of the first pyramid. As sources of meat, milk, and milk products, cattle have been the most valuable domestic animal species in much of the Old World for much of history and remain so on all continents today. And by drawing plows and providing manure, cattle made agriculture possible on land that farmers had previously been unable to till. Cattle also revolutionized land transport by providing a way to move goods in bulk.

Today, domestic cattle are very diverse, with about 800 recognized breeds. All derive from a now-extinct wild species called aurochs. Formerly widespread over Eurasia and North Africa, and similar to cattle except for its larger size, the last surviving aurochs is thought to have been killed in Poland in 1627. Was the domestication of this prize beast achieved by some genius herders just once in human history? If so, who were they, and when and where did they live? Did that one ancestral domesticated breed then spread over the Old World in ancient times, and are all modern cattle breeds descended from it? Or if one tribe of geniuses was able to domesticate the aurochs in Turkey, did some other tribe of geniuses do it in India at another time? The debate about domestic cattle origins is thus a model for similar debates about the origins of pyramids, wheels, and writing.

Even those of us who have never been to India know from pictures that Indian cattle look different from the European (actually western Eurasian) varieties now widespread in the Americas. Indian cattle, or zebu, have humps; many, but not all, traditional African breeds are also humped but European cattle aren't. Did ancient herders of the western and eastern subspecies of wild aurochs independently domesticate the ancestors of different modern breeds? And if so, can we believe th evidence of our eyes and conclude tha humped African cattle are most closely related to humped Indian breeds? Or wa there instead a single domestication of aurochs, with humped and humpless breed developing afterward?

Anatomists, physiologists, archeologists, cytogeneticists, and biochemist have been debating this question fo decades. Anatomists note that Indian African, and European cattle differ fron one another in more than their humps Further complicating the issue is the consideration that the anatomy of their hump differs between African and Indian breeds Could both have acquired the feature independently through convergent evolutior just as birds and bats independentl evolved wings? Physiologists note that Indian cattle and many African breeds hav similar physiological adaptations to a ho dry climate, and that these aren't found i European cattle. Cytogeneticists and biochemists note differences in the chromosomes and proteins of European and Indian cattle. The question is, did all thos intercontinental differences arise in th 8,000 years since cattle were domesticated? Or do the differences instead ster from independent domestications of a

Please turn to page 7

Masai boy with humped cattle, Salela, Tanzania

Lori Grinker; Contact Press Images

TECHNOLOGY UPDATE

500 miles from nowhere, it'll give you a cold drink or a warm burger...

NASA space flights inspired this portable fridge that outperforms conventional fridges, replaces the ice chest and alternates as a food warmer.

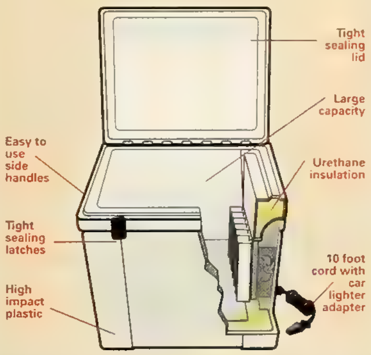
By Charles Anton

Recognize the ice cooler in this picture? Surprisingly enough, there isn't one. What you see instead is a Koolatron, an invention that replaces the traditional ice cooler, and its many limitations, with a technology even more sophisticated than your home fridge. And far better suited to travel.

What's more, the innocent looking box before you is not only a refrigerator, it's also a food warmer.

The refrigerator from outer space.

The secret of the Koolatron Cooler/Warmer is a miniature thermo-electric module that effectively replaces bulky piping coils, loud motors and compressors used in conventional refrigeration units. In the cool mode, the Koolatron reduces the outside temperature by 40 degrees F. At the switch of a plug, it becomes a food warmer, going up to 125 degrees.



NASA inspired portable refrigerator. Because of space travel's tough demands, scientists had to find something more dependable and less bulky than traditional refrigeration coils and compressors. Their research led them to discover a miraculous solid state component called the thermo-electric module.

Aside from a small fan, this electronic fridge has no moving parts to wear out or break down. It's not affected by tilting, jarring or vibration (situations that cause home fridges to fail). The governing module, no bigger than a matchbook, actually delivers the cooling power of a 10 pound block of ice.

From satellites to station wagons. Thermo-electric temperature control has now been proven with more than 25 years of use in some of the most rigorous space and laboratory applications. And Koolatron is the first manufacturer to make this technology available to families, fishermen, boaters, campers and hunters– in fact anyone on the move.

Home refrigeration has come a long way since the days of the ice box and the block of ice. But when we travel, we go back to the sloppy ice cooler with its soggy and sometimes spoiled food. No more! Now for the price of a good cooler and one or two seasons of buying ice, (or about five family restaurant meals), all the advantages of home cooling are available for you electronically and conveniently.

Think about your last trip. You just got away nicely on your long-awaited vacation. You're cruising comfortably in your car along a busy interstate with only a few rest stops or restaurants. You guessed it... the kids want to stop for a snack. But your Koolatron is stocked with fruit, sandwiches, cold drinks, fried chicken... fresh and cold. Everybody helps themselves and you have saved valuable vacation time and another expensive restaurant bill.

Hot or cold. With the switch of a plug, the Koolatron becomes a food warmer for a casserole, burger or baby's bottle. It can go up to 125 degrees.

And because there are no temperamental compressors or gasses, the Koolatron works perfectly under all circumstances, even upside down. Empty, the large model weighs only 12 pounds and the smaller one weighs just seven. Full, the large model holds up to 40 12-oz. cans and the smaller one holds six.

Just load it up and plug it in. On motor trips, plug your Koolatron into your cigarette lighter; it will use less power than a tail light. If you decide to carry it to a picnic place or a fishing hole, the Koolatron will hold its cooling capacity for 24 hours. If you leave it plugged into your battery with the engine off, it consumes only three amps of power.

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Chaos in the Solar System

Neil de Grasse Tyson

The ability to predict future events with precision is what distinguishes science from almost all other human endeavors. Daily newspapers often give dates for upcoming phases of the moon or the time of tomorrow's sunrise. But they do not report news items of the future such as next Monday's plane crash or next Tuesday's closing prices on the New York Stock Exchange. The general public knows intuitively, if not explicitly, that science makes predictions, but it may surprise people to learn that science can also predict that something cannot be predicted. Unpredictability is the basis of chaos. And unpredictability characterizes the future evolution of the solar system.

A chaotic solar system would no doubt have upset the German astronomer Johannes Kepler, who is generally credited with the first predictive laws of physics, published in 1609 and 1619. Using a formula that he derived from planetary positions on the sky, he predicted the average distance between any planet and the sun by knowing the duration of the planet's year. In 1687, Isaac Newton published the *Principia,* which contains the law of universal gravitation from which Kepler's laws can be mathematically derived.

In spite of the immediate success of his new laws of gravity, Isaac Newton remained concerned that the solar system might one day fall into disarray. With characteristic prescience, Newton noted: "The Planets move one and the same way in Orbs concentric, some inconsiderable Irregularities excepted, which may have arisen from the mutual actions of . . . Planets upon one another, and which will be apt to increase, till the system wants a Reformation." Newton implied that God might occasionally be needed to step in and fix things. The celebrated French mathematician and dynamicist Pierre-Simon Laplace had the opposite view of the world. In his 1799 four-volume treatise *Mécanique céleste,* he declared that the universe was stable and fully predictable. Laplace later wrote, "[with] all the forces by which nature is animated . . . nothing [is] uncertain, and the future as the past would be present to [one's] eyes." When queried by Napoleon Bonaparte on the absence of any reference to God in his treatise, Laplace replied, "Sire, I have no need of that hypothesis."

The solar system does, indeed, look stable if all you have at your disposal is a pencil and paper—with or without God. But in the age of supercomputers, where millions of computations per second are routine, solar system models can be followed for hundreds of millions of years. What thanks do we get for our deeper understanding of the universe? Chaos—which reveals itself through the application of our well-tested physical laws in computer models of the solar system's future evolution. Today's leading solar system modelers include Scott Tremaine and his colleagues at the Canadian Institute of Theoretical Astrophysics and Jack Wisdom and his colleagues at the Massachusetts Institute of Technology.

Chaos has also reared its head in other disciplines, such as meteorology, predator–prey ecology, and in most other places where there are complex interacting systems. To understand chaos as it applies to the solar system, one must first recognize that the difference in location between two objects—their distance—is just one of many differences that can be calculated. Two objects can also differ in energy, orbit size, orbit shape, and orbit inclination. It is therefore useful to broaden the concept of distance to include the separation of objects in these other variables as well. For example, two objects that are (at the moment) near each other in space may have very different orbit shapes. Our modified measure of distance would tell us that the two objects are widely separated.

A common test for solar system chao
begins with two computer models that ar
identical except for a small detail. For ex
ample, in one of the models, Earth might re
coil slightly in its orbit as a result of bein
hit by a small meteor. We are now armed t
ask a simple question: Over time, what hap
pens to the "distance" between these tw
nearly identical models? It may remain co
stant, fluctuate, or increase. If the distanc
between the two models increases expone
tially, then small changes to the system ar
extremely magnified over time, and th
ability to predict future behavior based o
well-known initial conditions is compro
mised. This is the hallmark of chaos. W
owe much of our early understanding of th
onset of chaos to Aleksander Mikhailovic
Lyapunov (1857–1918), a Russian mathe
matician and mechanical engineer whos
1892 doctoral thesis, "The Stability of Mo
tion," remains a classic to this day. (By th
way, Lyapunov committed suicide durin
the political chaos that followed the Russia
Revolution.)

It has been known since the work o
Newton that the paths of two isolated ob
jects in mutual orbit, such as a binary st
system, can be solved exactly for all of tim
No instabilities there. But as more objec
are added to the dance card, orbits not onl
become more complex but also more sens
tive to their initial conditions. In the sol
system we have the sun, its nine planets, an
sixty-plus satellites, along with innumerab
asteroids and comets. While this may soun
complicated, the story is not yet complet
Orbits in the solar system are further infl
enced by the sun's loss of 4 million tons
matter every second from the thermon
clear fusion in its core. (The matter is co
verted to energy that is subsequently r
leased as light from the sun's surface.) Th
sun also loses mass from the continuous
ejected stream of charged particles know
as the solar wind. And the solar system
further subject to perturbing gravity fro

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stars that occasionally pass by in their normal orbit around the galactic center.

To appreciate the task of the solar system dynamicist, consider that the equations of motion allow you to calculate, at any given instant, the net force of gravity exerted on an object by all other known objects in the solar system and beyond. Once you know the force on each object, you nudge them all (on the computer) in the direction they ought to go. But the force on each object in the solar system is now slightly different because everything has moved. You must therefore recompute all forces and nudge them again. This continues for the duration of the simulation, which in some cases involves billions of nudges. When you do these calculations or similar ones, you reveal that the solar system's behavior is chaotic: over time intervals of about 5 million years for the inner planets (Mercury, Venus, Earth, and Mars) and about 20 million years for the outer, "Jovian" planets (Jupiter, Saturn, Uranus, and Neptune), arbitrarily small "distances" between initial conditions noticeably diverge. By 100 to 200 million years into the model, we have lost all ability to predict planet trajectories.

Yes, this is bad. Consider the following example: The recoil of Earth from the launch of a single space probe can influence our future in such a way that in about 200 million years, the position of Earth in its orbit around the sun will be shifted by nearly 60 degrees. Combine the effects of all past and future launches, and we simply do not know where Earth will be in its orbit so far in the future. By itself, this ignorance seems benign. But note that asteroids in one family of orbits can chaotically migrate to another family of orbits. If asteroids can migrate, and if Earth will one day be in some unpredictable place in its orbit, then there is a limit to how far in the future we can reliably calculate the risk of a major asteroid impact and the global extinction that might ensue.

Should the probes we launch be made of lighter materials? Should we abandon the space program? Should we worry about loss of solar mass? Should we be concerned about the thousand tons of meteor dust per day that Earth accumulates as it plows through the debris of interplanetary space? Should we all gather on one side of Earth and leap into space together? None of the above, because even perfect information may not help. For example, the *Voyager* spacecrafts measured the masses of the Jovian planets with a high degree of precision, but some uncertainty remains. Simulations reveal that even if the masses of all planets were known exactly, our ability to predict the long-term evolution of the solar system would not improve.

A skeptical inquirer might worry that the unpredictability of a complex, dynamic system over long time intervals might be due to a computational round-off error or to some peculiar feature of the computer chip or computer program. If this suspicion were correct, then two-object systems might eventually show chaos in the computer models. But they don't. And if you pluck Uranus from the solar system model and repeat the orbit calculations for the Jovian planets, then the chaos goes away. Another proof that chaos is not the result of a computer glitch comes from simulations of Pluto's orbit, which has the greatest eccentricity and the most extreme orbital tilt of any planet. Under the influence of the Jovian planets, Pluto actually exhibits well-behaved chaos; small distances between initial conditions of two models lead to an unpredictable, yet limited set of trajectories. Most importantly, however, different investigators using different computers and different computational methods have derived similar time intervals for the onset of chaos in the long-term evolution of the solar system.

Apart from our petty desire to avoid extinction, there are broader reasons why one might like to study the long-term behavior of the solar system. With a full evolutionary model, dynamicists can go backward in time to probe the system's history—when the planetary roll call might have been very different from that of today. For example, some planets that existed at the birth of the solar system (5 billion years ago), could have since been forcibly ejected. Jack-in-the-box planets are not idle speculation; there exists a small chance that among our current nine, the innermost planet, Mercury, will be ejected from the solar system or will collide with Venus in several million years.

In four centuries, we have gone from not knowing the motions of the planets to knowing that we cannot know the evolution of the solar system into the unlimited future. It is a bittersweet victory in our unending quest to understand the universe.

Neil de Grasse Tyson is an astrophysicist with a joint appointment at the American Museum-Hayden Planetarium and Princeton University. He is the author of Universe Down to Earth, *published by Columbia Press.*

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by Joe Rao

Years ago, while strolling toward a street corner just after sundown, I noticed a small cluster of people apparently gazing at something down the block. My first thought was that an accident had occurred, but when I reached the corner, I heard people simultaneously exclaiming, "Look at the moon!" Turning toward the eastern sky, I saw why everyone was spellbound: just emerging over the horizon was the nearly full moon. It was enormous, appearing many times its "normal" size. As it rose in the sky, it began to shrink, and within an hour it had resumed its usual appearance.

That the moon seems much larger when it's near the horizon has been noted by almost everyone, and many have offered explanations for this effect. Aristotle thought that the moon's light passing horizontally through the earth's atmosphere caused the phenomenon. Karl Friedrich Gauss, an early-nineteenth-century philosopher, astronomer, and mathematician, was the first to make significant progress in solving the puzzle by proposing a novel solution. He thought the answer lay in the difference between the perceived image at the horizon, which provides the eyes with a scale for comparison, and the image perceived with the eyes raised to view the same object high overhead. Similarly, the nineteenth-century German physicist, Hermann von Helmholtz, known for his studies of how the brain processes visual information, reasoned that the moon appears larger near the horizon because we see it next to terrestrial objects and, as Gauss surmised nearly a half century earlier, our brain unconsciously assigns to it a dimension comparable to familiar objects such as trees and houses.

This month, the moon illusion is more pronounced because the full moon on the 12th falls just one day after perigee, when the moon is at its closest point to Earth. At this time, the moon's disk actually is a bit larger in our sky. It's therefore a great time to see how the illusion works. First, check your local newspaper or an almanac for the time of moonrise in your area on the 12th or for a day or two after. (Before the 12th, moonrise occurs during daylight.) Be sure to find a spot with a clear and unobstructed view of the horizon toward the east–southeast. Roll a sheet of paper into a tube about half an inch in diameter and about twelve inches in length and look through it, using one eye, at the enlarged moon; the lunar disk will instantly contract to its "normal" size. Then close the eye looking through the tube and open the other one; the moon will immediately return to its enlarged appearance.

The eye looking through the tube is never deceived, because when you observe the moon through it, your brain can't make an unconscious comparison with neighboring trees or buildings on the horizon. And the lens of your camera will not be fooled either: a photograph taken at moonrise and again later, when the moon is high in the sky, will show no discernible difference in the moon's size. If you've ever seen a photograph of an unusually large moon near the horizon, it was probably taken with a telephoto lens.

"Being here with you Felicia, with the stars twinkling high above, and the moon shining down upon us, I realize more than I ever did before, how little I know about astronomy."

THE PLANETS IN JULY

Mercury can be found 8 degrees to Venus's upper right from the 1st to the 6th. Thereafter, as it sinks back into the solar glare, it will gradually approach Venus, passing within only about a half degree of it on the morning of the 20th. Mercury will rival Sirius this morning at magnitude –1.5. But spotting this planetary duo, even from the southern United States (where they will rise a little higher), will be extremely diffi
cult. Scan low along th
east–northeast horizon wit
binoculars about half an hou
before sunrise. Mercury will ar
rive at superior conjunction o
the 28th.

Venus lingers in the dawn sk
through the first half of July. It
proximity to the sun makes th
planet nearly invisible. If you d
manage to locate Venus near th
horizon with binoculars, yo
may find it to be unexpectedl
brilliant in the morning twiligh
Venus will pass behind the su
(superior conjunction) in Augu
and return to the evening sky b
October.

Mars continues on its eas
ward course, trying to stay i
step with the sun. It sets an ave
age of three hours after the su
during July and fades slightly
it moves farther from the eart
The fat crescent moon is belo
and to the right of Mars on th
evening of the 3d.

Jupiter is near the meridia
at dusk and sets after midnigh
Its large, cloud-belted disk an
four bright satellites are a tre
for observers using even sma
telescopes. The waxing gibbo
moon will pass Jupiter durin
the daylight hours of the 9th. A
a result, you'll find Jupite
below and to the left (east) of t
moon on the evening of the 8
and at a similar distance belo
and to the moon's right (west)
the evening of the 9th.

Saturn, in Aquarius, rises
the late evening and moves
the south–southwest by sunris
Resembling a yellowish whi
"star," Saturn shines below t
waning gibbous moon late
the night of July 16-17.

The **Moon** is at first quart
on the 5th at 4:02 P.M., EDT; fu
moon is on the 12th at 6:49 A.M
EDT; last quarter is on the 19
at 7:10 A.M., EDT; and ne
moon is on the 27th at 11:1
A.M., EDT.

*Meteorologist Joe Rao is a gue
lecturer at the American M
seum-Hayden Planetarium.*

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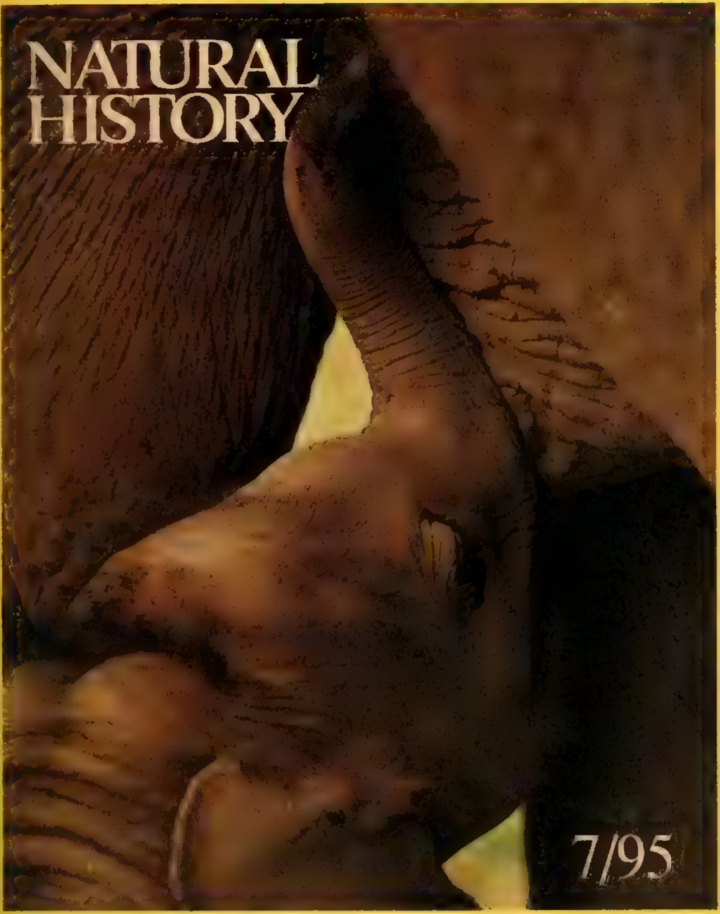

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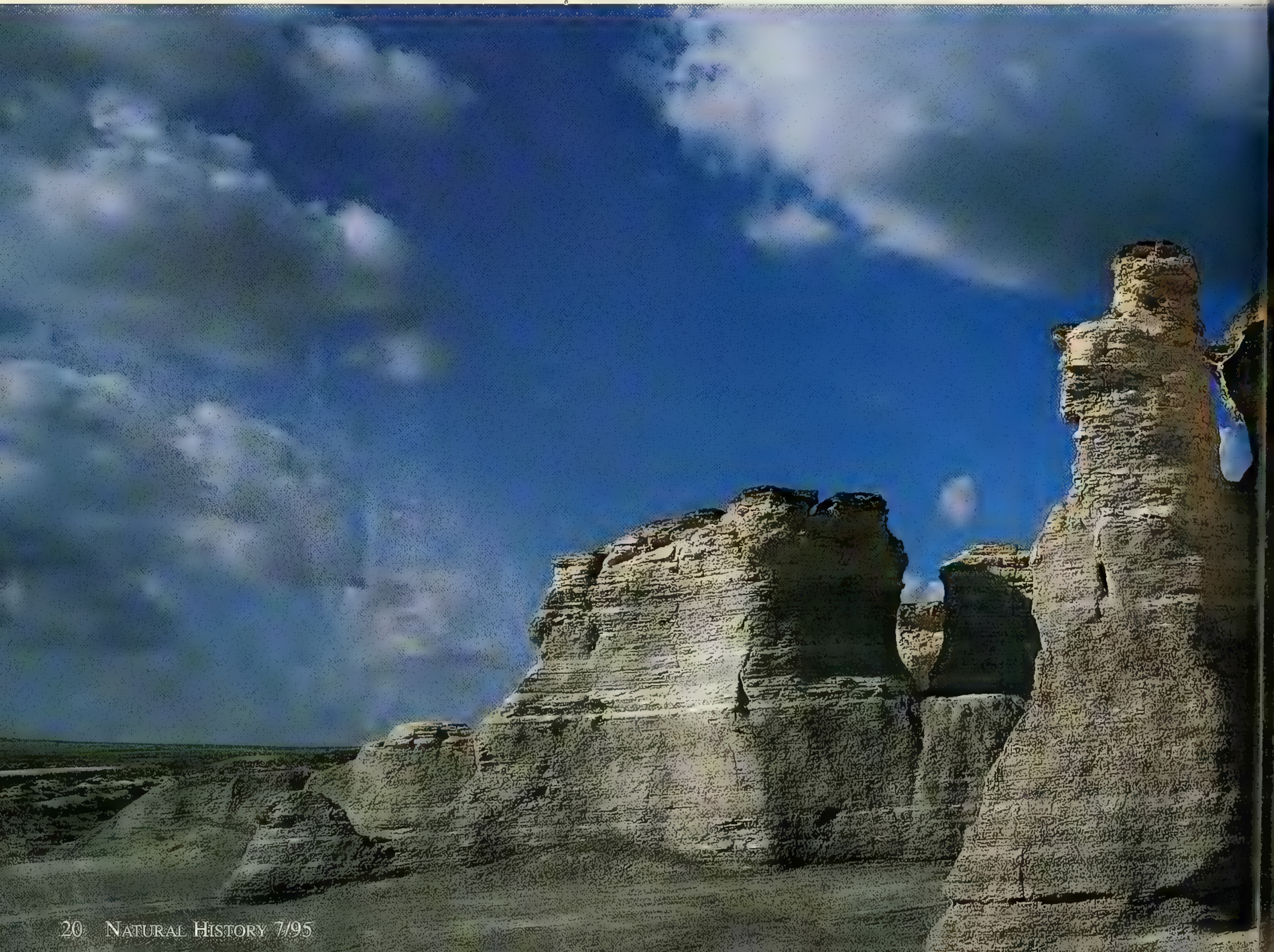
Monument Rocks, Kansas

by Robert H. Mohlenbrock

Not all of Kansas is flat, as you might suppose if your only knowledge of the state comes from the film *Wizard of Oz*. West of Kansas City, Interstate 70 climbs imperceptibly through an undulating landscape that encompasses the Flint Hills, a source of high-quality flint since prehistoric times. But then, sure enough, the rolling hills give way to a broad plateau, and you get the feeling that you can see westward forever. This is the eastern edge of the Great Plains, which rise at an average rate of eight feet per mile for more than 300 miles but are otherwise quite flat. Having driven westward from Illinois to the Rocky Mountains more than a score of times, I have come to dread the endless wheat fields, pastures, and patches of sunflowers that border I-70 across this stretch of Kansas and the eastern third of Colorado. So it was that on a recent trip, my wife and I decided to investigate the meaning of two small words printed in red in my well-worn atlas: Monument Rocks.

At Oakley, Kansas, about midway across the Great Plains, we turned south on U.S. Highway 83. After twenty miles, we saw geological formations rising to the southeast above the flat terrain. We continued on for another ten miles, crossing the Smoky Hill River and finally heading east on a county road. The nine-mile gravel road took a circuitous route, dropping down to cross a rocky wash of a tributary stream and then winding around to the main river. We were now a half mile from



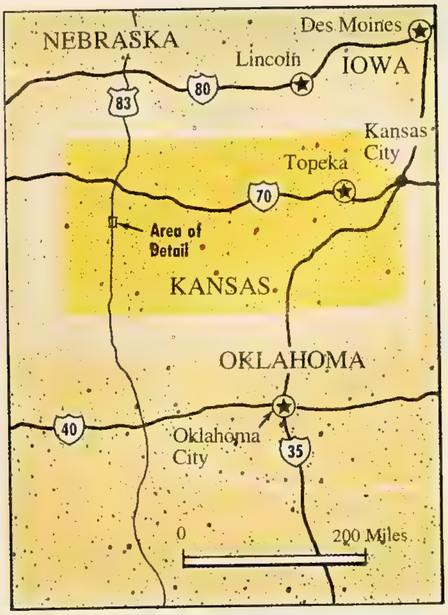
Monument Rocks, white pillars of chalky limestone that were landmarks to pioneers who trekked west 150 years ago.

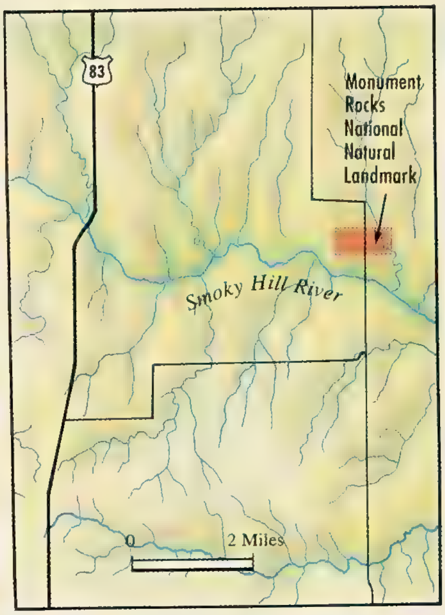
Nearly two dozen pillars, the tallest about forty feet high, stand within a ten-acre area, along with the remains of others that lie in crumbled heaps, having succumbed to erosion. The formations are the centerpiece of a 340-acre National Natural Landmark; a few more lie to the north of the landmark area. The rock forming the pillars is Niobrara chalk (an earlier name for the formations was the Chalk Pyramids). It is composed almost entirely of the remains of microscopic organisms, both plants and animals, that once lived in a vast inland sea. This type of rock occasionally preserves the remains of larger organisms from the Age of Dinosaurs—fish, marine reptiles, even flying reptiles—attracting paleontologists to this part of Kansas. The inland sea, which covered much of the continent for half a billion years, was gradually displaced beginning 70 million years ago by a slow uplift of the continent. According to geologist Donald Trimble, this uplift created the Black Hills of South Dakota, but otherwise caused only small undulations in the surface of what is now the Great Plains.

To the west, however, the Rocky Mountains rose rapidly, forming a chain extending from Mexico to Alaska. Sedimentary rock eroded from the mountain crests and was washed eastward by rivers and streams, to be deposited over the Plains in

Ric Ergenbright

Joe LeMonnier





Monument Rocks

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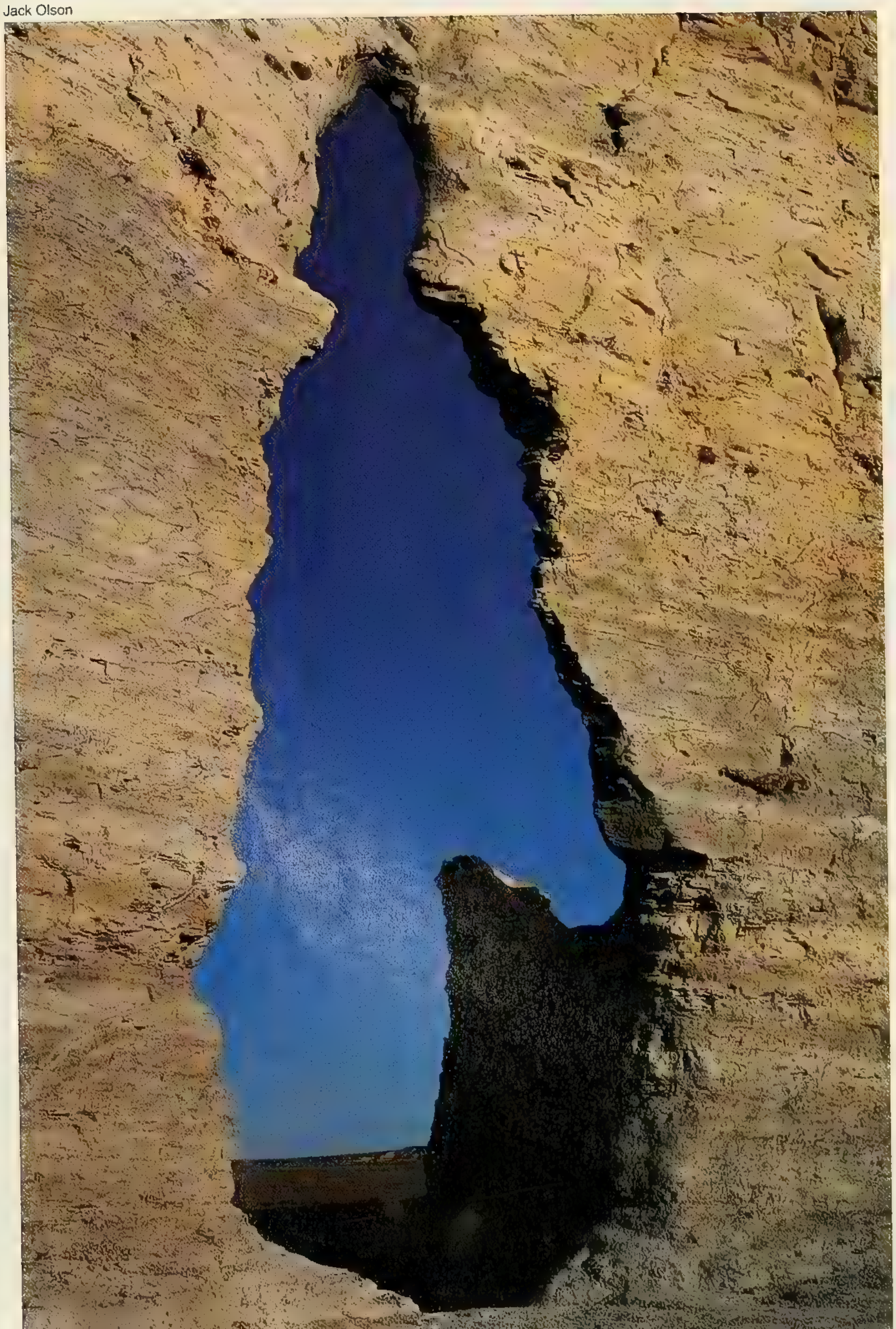
the form of gravel, sand, and mud. Vegetation thickened in this new alluvium, providing abundant food for such prehistoric herbivores as *Triceratops*, a three-horned dinosaur. Following the extinction of the dinosaurs about 65 million years ago, the developing grasslands were grazed by such ungulates as camels, tapirs, rhinoceroses, and horses.

About 10 million years ago, Trimble concludes, the entire western part of the continent experienced a further general uplift. The streams that had been depositing their sediment on the Plains began to flow more swiftly, cutting through the soil. This created the rugged terrain of the Pecos Valley and Edwards Plateau in present-day New Mexico and Texas and the Missouri Plateau in parts of North Dakota, South Dakota, Montana, and Wyoming. The great central area of the Plains, which we now refer to as the High Plains, remained little affected by these events. But eastward-flowing rivers originating in the High Plains of eastern Colorado and extreme western Kansas—among them the Smoky Hill, Saline, Solomon, and Republican rivers—began to cut through parts of west-central Kansas.

As the Smoky Hill River eroded the land surface, it formed a series of valleys, or draws, separated by narrow ridges. In the process, it carved its way through the chalky limestone, leaving exposed the Monument Rocks that we see today. The soft chalk, which in places is actually a chalky shale, is surmounted by a thin, erosion-resistant cap of harder, purer limestone.

The only plants living today on the spires and pinnacles of Monument Rocks are obscure yellow, orange, and brownish lichens, organisms that consist of cohabiting algae and fungi. But plants typical of

Jack Olson



Eroding rocks, left, consist of chalk and chalky shale, the ancient sediments of a vast inland sea. Right: Plains grasses and wildflowers the semiarid environment of the Great Plains—midsize grasses and short grasses intermixed with prairie and Plains wildflowers—grow in the surrounding dry, flat terrain. The midsize grasses, such as little bluestem, side oats grama, sand dropseed, needlegrass, western wheatgrass, and June grass, provide shade for the lower-growing species, such as blue grama, buffalo grass, and three-awn.

Many Plains wildflowers, especially those of the goosefoot, amaranth, and smartweed families, have tiny, obscure flowers. Showier species are purple prairie clover, lupine, prince's plume, spider flower, plains milkweed, checker mallow, Indian blanket, gumweed, purple coneflower, sunflower, blazing-star, wild tansy, and goldenrod. Cactuses include a prickly pear and a *Coryphantha.*

Before European American settlers displaced the Native Americans who lived and hunted on the Great Plains, the area was mostly a treeless grassland grazed by enormous herds of bison. Because the climate was dry and hot, trees grew only along waterways. Even today, the only woody plants in the vicinity of Monument Rocks can be found along the Smoky Hill River and its tributaries. Among them are American elm, hackberry, cottonwood, green ash, peach-leaved willow, coyote willow, and two nonnatives—Siberian elm and salt cedar.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the U. S. national forests and other parklands.

David Muench

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SCIENCE LITE

True Lies

Talk about your ice capades . . .

by Roger L. Welsch

My hometown is Dannebrog, Nebraska, whose principal distinction is that it is also the home of the National Liars Hall of Fame and its annual Tall Tale contest. Okay, the Hall of Fame is actually just a corner in the back of Eric's Big Table Tavern, and the contest itself consists mostly of opening a couple of dozen envelopes, some chin scratching, and a nod. But just the knowledge that Dannebrog hosts the Liars Olympics is enough to transform daily life in this otherwise run-of-the-mill village. Which is to say, you can't hardly comment on anything the least bit extraordinary without someone saying, "Yeah, sure, right, uh-huh."

For example, not long ago I was picking up some supplies at the local lumberyard and I asked Bob Peterson how his trip to Canada had gone, mentioning that I thought it was a little unusual to go north from Nebraska in the wintertime. He said that quite to the contrary, winter is the best time for such a trip, because you avoid all the usual tourist traffic and you can camp without worrying about bugs. And winter and cold in the northlands have other attractions, as he learned when he went to Jasper National Park in Alberta and ran into the iceboat project up there.

"Iceboat?" I asked innocently. "I used to have an iceboat. Sail, skates, that sort of thing. I can imagine up there in the cold lake country, iceboats are just the thing."

"No," Bob said. "These boats—ships really—didn't go on top of ice. They floated in the water like regular boats but were made out of ice. During the Second World War the Allies thought they'd make some ships out of ice so they wouldn't be so easily detected by radar or sonar. And they'd be cheaper than steel ships."

"Yeah, sure, right, uh-huh," I said. "Bob, I'll jot that one down and you'll be eligible for the grand prize when we do our judging over at the Hall of Fame."

"No, Rog, I'm not joking. Actually, the boats weren't made just out of ice. Sawdust was mixed in with the frozen water. Turned out the combination was almost bulletproof. The story is that the ice-sawdust mixture was so strong that at a demonstration, bullets fired into the stuff ricocheted around and nearly killed some of the distinguished visitors there for the test. They called the stuff Pykrete after Geoffry Pyke, who thought up the mixture in the first place. You know—*Pyke* plus *concrete*. They figured U-boat torpedoes would barely scratch the stuff."

"Yeah, sure, right, uh-huh."

"They figured their ice ship would be nearly a football-field wide, six long, and the whole thing was going to be a good twenty times bigger than any other ship afloat. I don't know why, but they called them Habakkuks."

"Yeah, sure, right, uh-huh."

"Two thousand crewmen, twenty-six engines, weighing two million tons."

"Yeah, sure, right, uh-huh."

"Lord Mountbatten had the idea originally. Patrols were having a heck of a time trying to destroy icebergs after the *Titanic* went down, so he figured icebergs would make great military posts. They were going to use the ships as flattops for submarine defense and air cover for the invasion of Europe. They thought of them as artificial icebergs."

"Yeah, sure, right, uh-huh."

"Winston Churchill thought it was a great idea."

"Yeah, sure, right, uh-huh."

"In the winter of '42 to '43 they built a one-fiftieth-size scale model of an ice ship in Jasper Park. The model was ten meters wide, twenty meters long, seven meters deep. Weighed a thousand tons. Fifteen men built it in two months. The remains—not the ice, of course, but the pipes and stuff from the refrigeration system—are still visible to divers exploring the bottom of Patricia Lake.”

“Yeah, sure, right, uh-huh.”

I loaded up my lumber and hardware and thanked Bob for his story, expressing special appreciation for the nice touch of mixing sawdust in with the ice, he being a lumberyard proprietor and all. “But,” I added, “as an old hand at this tall tale stuff, I would suggest that the next time you submit an entry to the liars contest, Bob, you tone down your exaggerations. Try something like, ‘three times bigger than any other ship afloat’ and maybe ‘one thousand crewmen.’ Stories are more popular if you make them just a touch closer to reality and if you’re not quite so generous with your hyperbole. Take it from me, Bob, it will work much better.”

I guess Bob didn’t take my friendly advice in the spirit it was offered because he ust mumbled something about how an honest man doesn’t have a prayer in a own full of liars, turned on his heel, and went back to his office.

Out of curiosity I wrote to the folks at he Jasper National Park but apparently Bob had already filled them in on Dannebrog and our National Liars Hall of Fame. The park staff had already cooked up a bunch of nonsense about berg ships and bulletproof ice and aircraft carriers the size of Massachusetts. They had even put ogether a nice story about how the ships got their name: The project and eventually he ships were called Habakkuks after a book of the Old Testament, in which God says to the prophet Habakkuk: “Behold among the nations and regard, and wonder marvelously; for I will work a work in your days, which ye will not believe, hough it be told you.”

Yeah, sure, right, uh-huh.

Folklorist Roger L. Welsch lives on a tree arm in Dannebrog, Nebraska.

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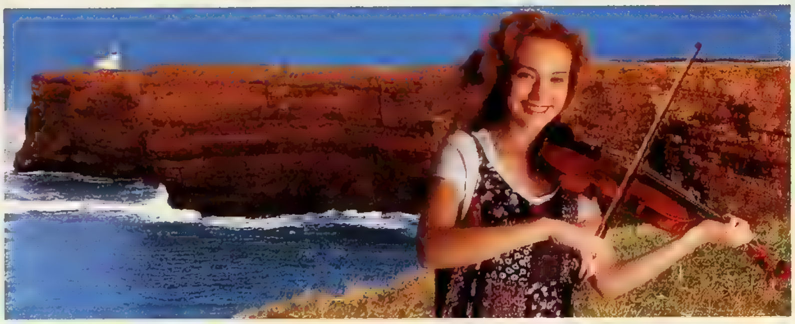

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NEWFOUNDLAND & LABRADOR

To Each His Zone

On Northwest Coast beaches, drifting crab larvae unerringly find snug harbors

by Gregory C. Jensen

Most people strolling along a boulder-strewn beach in the Pacific Northwest notice the seaweed, mussels, and barnacles that live along the beach's slope. Marine biologists have long been intrigued by the orderly arrangement of these organisms into distinct bands, or zones, which can vary in width from mere inches to scores of feet depending on the steepness of the beach. During the six and a half hours between high and low water, the ebbing tide gradually exposes these intertidal organisms to a wide range of environmental conditions. Those highest on the beach may be stranded for half a day or more, sometimes facing extremely high, desiccating temperatures, while those at the lowest levels have infrequent and much shorter periods of exposure.

At the lowest levels of the rocky beaches along the Northwest coastline, where the rocks are underwater most of the time, various kelps and other types of brown algae blanket the boulders at low tide. The next highest zone is often distinguished by another group of seaweeds, the green algae, whose thin sheets and strands coat the rocks. These two bands are within the domain of the two-inch-wide flattop crab, *Petrolisthes eriomerus,* whose extremely flattened body allows it to live on the underside of large boulders. A member of the porcelain crab family, related to hermit crabs, the flattop sports brilliant blue mouthparts and a blue spot on each of its disproportionately large claws.

Another, closely related species—the flat porcelain crab, *Petrolisthes cinctipes*—inhabits the next two higher bands of the intertidal zone. The lower band frequently supports large colonies of mussels, while the boulders in the upper band are adorned with clumps of fucus, a brown alga. Flat porcelain crabs have bright red mouthparts and claw spots, but are otherwise difficult to distinguish from the flattop, or bluemouth, species. Both share many of the same areas of rocky shoreline along the west coast of North America, from northern British Columbia to southern California, and are the only two members of their genus over much of this range. Widespread in distribution, porcelain crabs attain their greatest diversity in tropical and sub-

Although they may jettison a claw when handled, porcelain crabs are anything but delicate when fighting among themselves.

A large male flattop crab (far left) and a flat porcelain crab (left) battle for space on the underside of a rock. Despite their greater pugnacity, flattops generally lose such contests.

Gregory C. Jensen

Zoeae look so unlike their parents that early naturalists classified them as entirely different organisms.

tropical waters: one scientist collected seventeen species in a single day on a beach in Panama.

Unlike most crabs, which are predators or scavengers, porcelain crabs are filter feeders, using specialized, netlike mouthparts, or maxillipeds, to strain plankton and other small particles from the water. The red-mouth and blue-mouth species of the Pacific Northwest are fairly typical. When the tide is out, these crabs cling to the undersides of boulders for hours, waiting for the incoming tide to cover them again. Both species feed by day or night, whenever the tides carry particles of food to them. In moving water they filter passively, extending their fanlike maxillipeds into the current for several seconds at a time, then retracting them to transfer food into the mouth. In calm conditions they filter actively, rapidly sieving the water with alternating strokes of their maxillipeds. In addition to filter feeding, they may emerge from hiding and climb onto submerged rock surfaces at night, using dense tufts of branched hairs on their claws to sweep up food. Blue-mouths have much larger and thicker "dust mops" than red-mouths, and spend much more time sweeping rocks.

In addition to collecting food, the brightly colored maxillipeds may also help the two closely related species of porcelain crabs identify suitable mates. During courtship, for example, a male blue-mouth waves his strikingly colored mouthparts at a female while also displaying the blue spot in the gape of his claws. (In central California a third, very similar species with blue mouthparts and red spots on its claws lives on the same rocky beaches. One has to wonder about the possible color combinations that might occur when seventeen species occupy the same location, as on the beach in Panama!)

Porcelain crabs have often been described as extremely fragile because they may jettison a claw when handled. Yet they are anything but delicate when competing for space with other species of crabs or when fighting among themselves. As the little crabs jockey for position beneath the rocks, they often use their oversized claws to deliver backhanded slaps and pushes to their fellows. Although such fights rarely result in injury, they establish and maintain social hierarchies: large males claim the areas with the best water flow. Once dominance has been established, the crabs will tolerate crowding so long as neighbors do not impede their feeding. But if a crab lacks room in which to extend its maxillipeds, it will resort to a good hard push to free up some space.

On rocky beaches near Washington's Pacific coast, red-mouths inhabit a relatively narrow band near the middle of the beach's intertidal zone. Immediately below it are large numbers of blue-mouths whose populations extend far below the lowest tides. Studies of various sessile or very slow-moving animals such as barnacles or mussels have shown that an organism's tolerance for heat or desiccation at low tide determines the upper limits of its beach zone, while the lower edge of the zone is usually defined by interactions with predators or competitors that have even less tolerance to exposure.

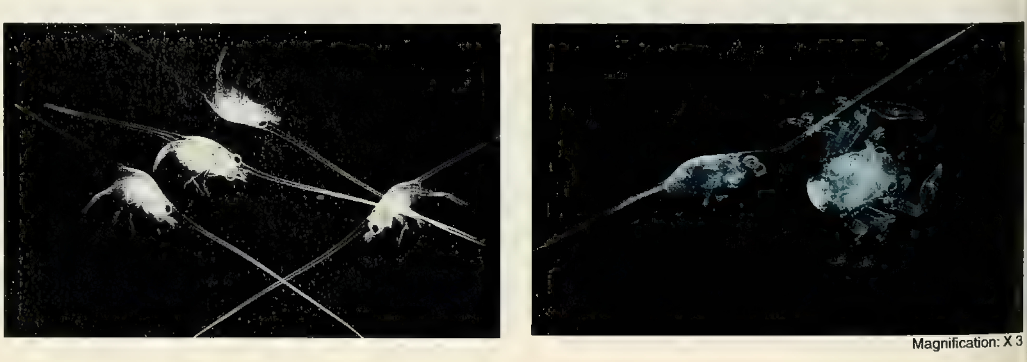
I wanted to know what determines which zones the porcelain crabs inhabit. Are the two species on the Washington coast physiologically incapable of living in each other's zones? Does one species exclude the other by outcompeting it? How are the particular zones perpetuated?

My first experiments indicated that the upper limit of blue-mouth distribution is set by physical factors. When transplanted to a slightly higher band, blue-mouths quickly succumb to heat stress during low tides on hot, sunny days.

To find out whether red-mouths were equally inflexible, I placed some in plastic-mesh cages anchored within the beach's lower zone. They not only survived there but even grew as well as those living at their normal level. Others that I kept underwater in aquariums for years also showed no ill effects. Yet I never saw the wild red-mouths encroaching on blue-mouth territory.

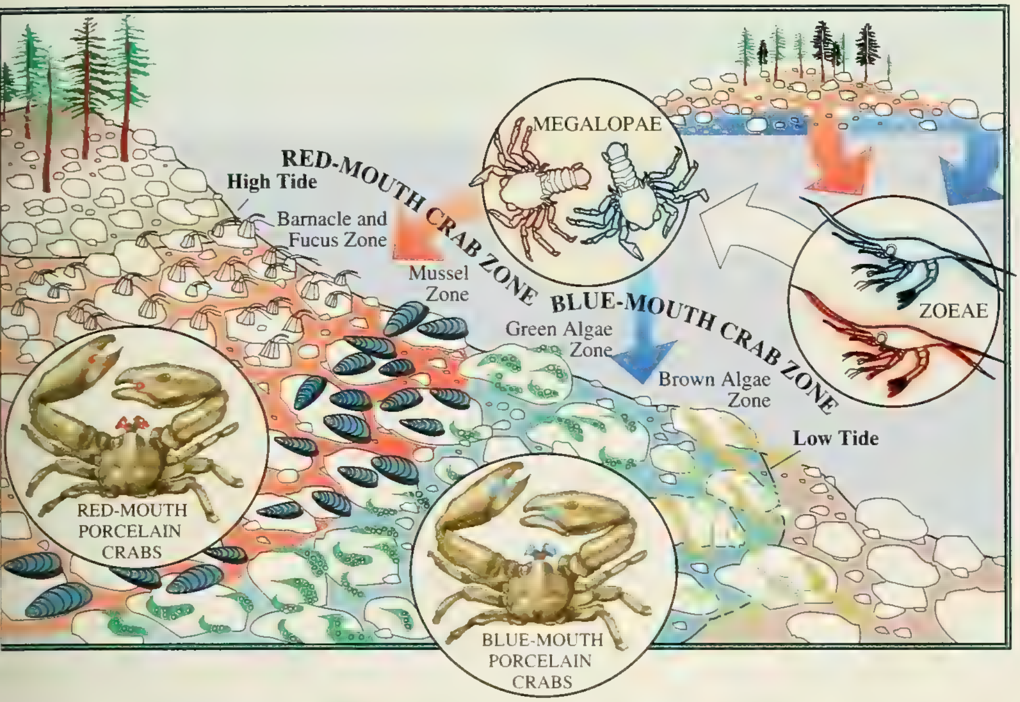
Why don't the red-mouths venture down the beach into blue-mouth zones? Considering the similarities of the two species, the most logical explanation was that blue-mouths were able to outcompete red-mouths at the lower levels. Compared with red-mouths, blue-mouths are far more aggressive, less tolerant of crowding, and more inclined to pinch. When I designed competition experiments pitting the two species against each other, I expected the blue-mouths to assert their dominance.

Surprisingly, the blue-mouths seemed virtually helpless in the presence of red-mouths, which were able to bulldoze them at will. Even when given the advantage of first access or



Porcelain crabs emerge from eggs as tiny, round hatchlings but sprout long spines on reaching open water, right, where they hunt other planktonic animals. Eventually, these zoeae become three-quarters of an inch long, molt, and transform into megalopae. Far right: A megalopa floats next to its cast-off exoskeleton; it will now abandon its predatory ways and become a filter feeder.

Photographs by Gregory C. Jensen



Larvae of two closely related kinds of porcelain crabs find their way to appropriate habitat by homing in on adults of their own species. For diagrammatic purposes, the larval stages have been drawn in blue and red; they are actually transparent and unpigmented.

Joe LeMonnier

arger individuals, blue-mouths still lost to their slightly stockier, less aggressive—but much stronger—relatives.

The red-mouths' ability to physically dominate the blue-mouths seemed to challenge the old assumption among ecologists that species ower on the beach hold a competitive advantage over those at higher levels. Red-mouths, like all ilter feeders, have to be immersed in order to eat, yet this species lives high on the beach, exposed to air for many hours each day. Since it can win whatever space it likes, why not move to a lower zone, evict a few blue-mouths, and take advantage of the extra feeding opportunities? This was exactly what happened in my laboraory tank with artificially generated tides.)

The resolution of this apparent contradiction came after I left Washington State to study crabs at the Bamfield Marine Station, on the west coast of Vancouver Island, British Columbia. Here the wo species of porcelain crabs arranged themelves very much as they did in Washington, but heir zones often overlapped slightly. On two beaches, however, large numbers of red-mouths lustered within the lowest intertidal zone, where blue-mouths would be expected. When I ompared samples of sediments from these two ites with those of other areas, I discovered that he red-mouths seemed to live only where little or no fine sand or sediment lay under rocks. A blurred boundary between areas of low and high oncentrations of sediment occurred farther down on many British Columbian beaches, alowing a slight overlap of the two zones, while in Washington an abrupt change from coarse gravel o fine sand marked the border between the two pecies.

To test whether the absence of fine sediment was indeed critical to the red-mouth's choice of zone, I cleared all porcelain crabs from a portion of a beach in British Columbia and rearranged the rocks into six long piles perpendicular to the shoreline, extending from the blue-mouth zone upward through the red-mouth zone. Three piles rested on the existing beach materials, their midpoints at the transition between the coarse gravel and cobble of the upper zone and the sand in the lower zone. The other three piles differed in only one respect: the sand in the lower half of each pile was replaced with sunken concrete blocks. Several hundred tagged red-mouths were released all along these piles. After a month, virtually all the red-mouths had either abandoned the lower half of the piles resting on beach sand and emigrated to higher zones, or had moved into the lower zones of the piles that were resting on concrete blocks. Now I had my answer: Red-mouths are not driven out of the lower zones by blue-mouths but prefer the sediment-free rocks seldom found on the lower beach. The boulders resting on concrete effectively mimicked conditions higher on the beach, providing sand-free spaces under the rocks. Red-mouths enjoy similar conditions in thick beds of sea mussels. Here, protected within the sediment-free interstices of the bed and with access to good water circulation, densities of adult red-mouths can exceed 300 crabs per square foot.

In sediment-free mussel beds, the density of adult porcelain crabs can exceed 300 per square foot.

Why red-mouths differ from blue-mouths in their tolerance to sand and sediment has yet to be determined, but seems likely to be related to their feeding methods. Of the two species the red-mouth is less inclined to actively filter, relying instead on water motion to carry food to its protected position. It may require turbulent conditions, which only occur near the open coast. In contrast, blue-mouths can live in the calm, sheltered waters of Puget Sound, where their ability

Gregory C. Jensen

Sheltered from predators, a juvenile porcelain crab feeds beneath the claw of a large adult, above. On the coast in Washington's Olympic National Park, opposite, brown algae, barnacles, and mussels form distinct zones of intertidal life.

Using dense tufts of branched hairs on their claws as "dust mops," the crabs can gather food by sweeping rocks.

to obtain food either actively or passively allows them to range over more kinds of habitats.

While the rock pile experiments helped to explain why the two species occupy separate beach zones, they did not address the question of how the crabs get there in the first place. Female crabs brood their eggs on the underside of their abdomens; the hatched eggs release larvae, known as zoeae, to the sea. In this first larval stage, the zoeae look so unlike their parents that early naturalists classified them as entirely different organisms. After weeks or months of drifting amid plankton, the zoeae must find a place to spend their adult lives. To make this transition, they shed their spiny exoskeleton and emerge as magalopae, an intermediate larval form. At this stage, they begin to seek a place to live. When at rest, the megalopa resembles a small crab, but it can swim like a shrimp, propelling itself forward with oarlike abdominal appendages.

When I began my study, virtually nothing was known about how larval crabs find their place on the beach. Their wide dispersion and tiny size, and the difficulties of raising them in captivity, have been major obstacles to observing their behavior. In 1987, however, I was fortunate enough to gather porcelain crab larvae shortly after they had settled on a beach. I noticed immediately that the megalopae of each species settled only within the zone inhabited by adults of the same species—and only under rocks occupied by many adults.

Had the juveniles selected these locations or were they merely survivors of a more widespread, indiscriminate settlement? The answer came when porcelain crab megalopae began appearing in the mesh cages I had anchored in the intertidal zone to confine adults for zonation experiments. All settled near adults of the same species. Such behavior had never before been observed in any kind of crab, shrimp, or lobster.

To find out what was attracting the megalopae, I decided to experimentally alter conditions on the beach between tides. First, I put concrete patio blocks in mesh cages and placed them within both the red-mouth and blue-mouth zones. Next, I placed adult red-mouths in some of the cages as "bait," and anxiously waited to see what would happen. Sure enough, a large number of red-mouth megalopae settled into the cages housing adult red-mouths, regardless of tidal zone, while avoiding the empty cages or those containing blue-mouth adults. Likewise, when I transplanted adult blue-mouths higher up the beach (during cool weather to insure their survival), their megalopae unambiguously homed in on adults of their own kind.

To test whether the juveniles were attracted by some sort of waterborne cue, I confined adult crabs to chambers that allowed water circulation but prevented the adults inside from being seen or touched by incoming megalopae. Even under these conditions the megalopae found the adults, indicating that they probably use chemosensory abilities to locate them.

Megalopae may swim to shore or hitch rides on driftwood or other flotsam. Once on the beach, they can skip from rock to rock in search of adults. After making contact with adults, the megalopae settle down, and soon their abdominal swimming appendages shrivel up. This change can occur within two days when adults are near; in the absence of adults, however, the megalopae can continue swimming for up to three weeks.

Newly settled crabs are tasty morsels for many kinds of fishes. Porcelain crab megalopae would seem especially susceptible to such predators; they are relatively slow moving, unable to bury themselves in sediment, and conspicuous when filter feeding. But they can find a safe haven among adults of their own species, which, unlike many other adult crabs, do not attack their young. By occupying spaces between and beneath larger crabs, they are protected from predation by small fishes that live under the rocks. Juveniles can safely cluster with adults for nearly a year after settlement, at which time they may begin to emigrate to other rocks. Such use of unrelated adults for protection is extremely rare among marine invertebrates, and is known to exist only among sand dollars and one species of sea urchin.

Porcelain crabs have been able to adopt a number of simple strategies that greatly reduce the risks associated with their settlement and juvenile life on wave-swept, rocky beaches. Instead of having to sense sediment composition, water circulation, or tide height in their habitats, the megalopae need only find adults of their own species. Once nestled among their well-armed, but harmless, rockmates, they remain protected from most predators, insulated in their self-perpetuating safety zones. □

In Plain Sight

In the open tundra, only an exquisitely camouflaged nest remains hidden

by Bernd Heinrich

I have never forgotten the first bird nest I found. I was eight years old, and as I peered into it, I was overwhelmed by its artful construction and by the beauty and symmetry of the small, greenish blue eggs it cradled. That birds would actually emerge from these strange productions of nature seemed to me otherworldly. Over the years, explanations of how this is indeed possible have never dulled my sense of awe upon spotting eggs in a new nest, particularly one with an unfamiliar design.

In New England, where I now live, forests provide birds with nearly endless places in which to hide their nests. The slate-colored junco builds its nest on the ground at the base of a grass hummock, curtaining it off with the dead grass of the previous year. The winter wren tucks its nest into the upturned root of a fallen tree. The nuthatch hammers a nest cavity into an erect, rotten stump. A redstart "fills out" the crotch of a tree fork, camouflaging the nest with lichens so that it blends in with the bark. The kinglet builds a green nest by weaving sprigs of moss into the thick twigs of a spruce.

Having graduated from searching for nests and eggs of most of the common songbirds, I longed to go to the far north, the breeding mecca for many of the elusive shorebirds. Migrating the length of the continent, they mate and raise their chicks in some soggy spot in the trackless tundra before making the return trip south. The tundra is like a living rug intricately woven from a large assemblage of small plants. In this treeless habitat, bird nests cannot be tucked away from predators as easily as in the forest. Here, eggs—especially those of larger birds—are exposed to protein-starved predators with keen senses. Wolves, arctic foxes, ravens, gulls, and long-tailed jaegers are eager to take eggs wherever and whenever they can, and the guileful art of protecting the tender embryos has been perfected by birds over millions of years. To find their nests, I knew that I would need either great skill or pure luck, and if I were to find any, I'd bet on the luck. I was eager to give it a try, however, and my wish came true when I landed in Kotzebue, a small village on the Alaskan coast just north of the Arctic Circle.

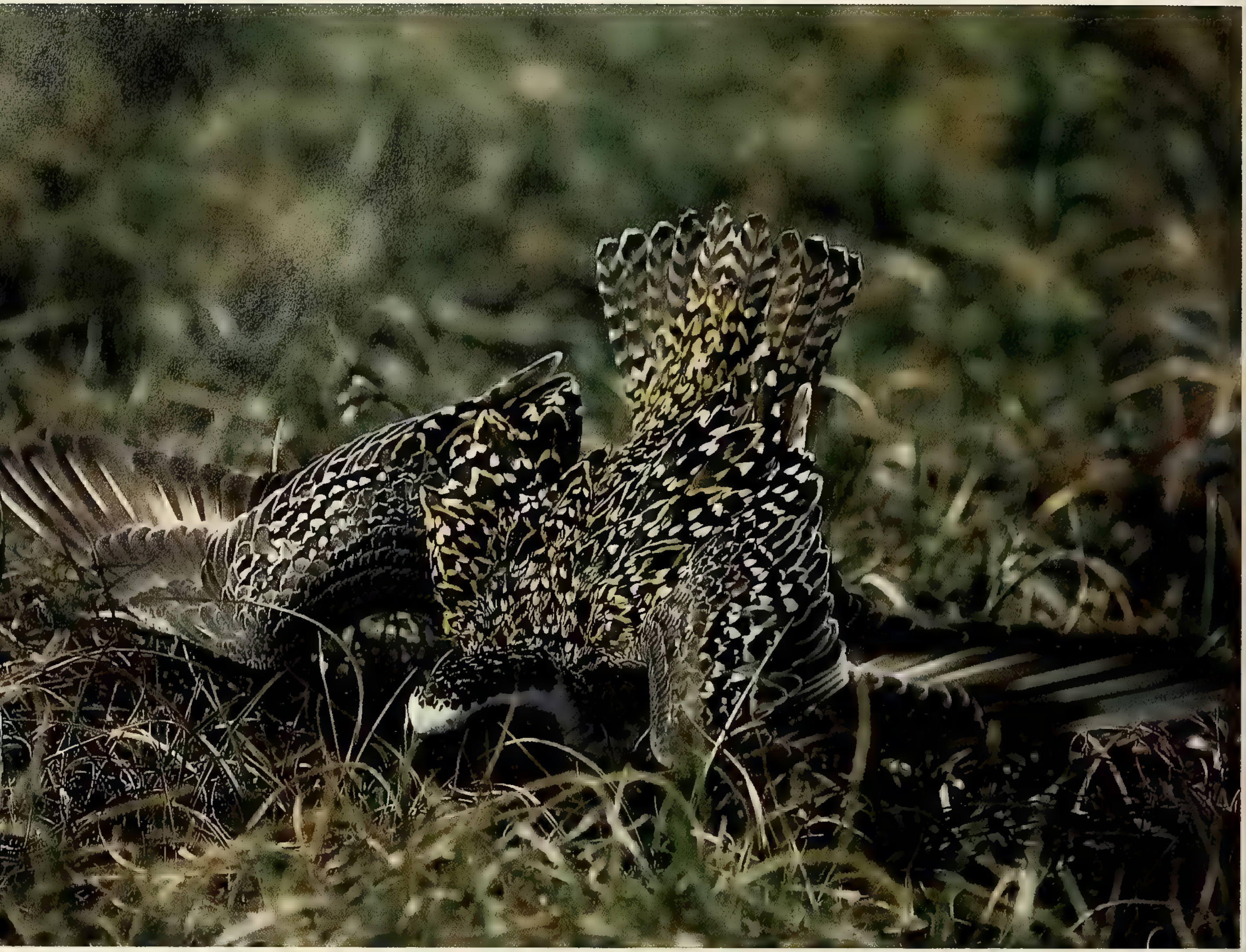
With four friends and my nephew Charles Sewell, I had come to canoe down the Noatak River, which originates on the southern slopes of

I led my nephew to within four feet of the nest, but he was unable to see the eggs until I pointed them out.

The first of four to hatch, this American golden plover chick is as hard to spot amid the tundra grasses as the three remaining eggs.
Kevin T. Karlson

Mud flats and gravel bars form the banks of Little Cottonwood Creek where it joins the Noatak River.
Fred Hirschmann

Having graduated from searching for nests of the most common songbirds, I longed to go to the far north, the breeding mecca for many of the elusive shorebirds.



In an effort to lure predators away from its nest, an American golden plover feigns a broken wing.
Kevin T. Karlson

the Brooks Range in the Gates of the Arctic National Park and flows 400 miles west to Kotzebue Sound and the Chukchi Sea. The only settlement along the entire river is the small village of Noatak, some 50 miles north of Kotzebue. We would be canoeing through this vast, undisturbed wilderness in late June, at the height of the waterfowl breeding season.

We had arranged to have a bush pilot fly us 400 miles inland to Pingo Lake, the small tundra pond where we were to begin our journey. From the seaplane, the view through the plexiglass seemed dreamlike. The Noatak far below looked like a coiled, silver snake winding across a greenish brown landscape. The ground seemed to have the texture of moss. Many crescent-shaped ponds dotting the tundra were the remnants of ancient oxbows, abandoned meanders of the river, which seemed to follow an arbitrary course over the vast plain. Occasionally, I spotted a pair of snowy white swans at the edge of one of the ponds, but from that height, we could see no other wildlife. Were there really wolves roaming down there? Where were the millions of nesting shorebirds and waterfowl?

I was jarred back to reality as the plane's pontoons touched down on the water's surface. Myriads of ducks swam placidly in rafts, and nervous phalaropes tarried near shore. Buck Maxim, our pilot, wasted little time unlashing our canoes from the plane's belly. Within minutes, we were standing at the edge of the pond with our gear piled in our canoes, watching the plane recede to a speck on the distant horizon. We were alone—hundreds of miles from the nearest village. Adjusting to the stillness, I soon heard the familiar songs of a robin and a yellow warbler, which seemed out of place here.

To reach the nearby river, we had to drag our loaded canoes through a willow thicket. The three- to five-foot-tall willows had been heavily browsed—perhaps by moose that had left their tracks imprinted in the mud. Nearby was a family of gray jays, its young already out of the nest. Not a spruce tree, with which I usually associate gray jays, was in sight. The staccato call of a Wilson snipe filled the air, and a pair of ravens flew overhead, high and silent.

Eager to be on our way, we shoved our canoes into the water and sped along with the swift current. For hours, we heard only the murmur and hissing of the river and the steady, rhythmic dipping of our paddles. Brown and swollen with meltwater, the river tore at the banks, eating them up at every turn. On the outside of each curve, the rushing water gouged caverns under the banks, and chunks of tundra fell into the river. We scanned the freshly exposed permafrost for bones and possible mammoth tusks. Where the current slowed on the opposite bank, it deposited gravel bars on which purple patches of fireweed and erect, deep crimson peas grew. Now and then, we spotted bleached moose and caribou antlers among the flowers.

We aimed to canoe at least forty miles each day so that during our two-week trip we would have four full days to rest, fish, and explore the tundra. On our rest breaks from hard paddling, we clambered up the steep banks to survey the tundra, which was in full bloom—a vista of pale yellow arctic poppies swaying in the breeze all the way to the horizon. Although the flowers varied from place to place, three colors predominated: yellow, purple, and white. When the sun came out so did the butterflies: yellow *Colias*, brown *Bolaria*, and the small, pale arctic blue. But most of the time all the insects, except the ubiquitous mosquitoes and occasional bumblebees, remained grounded because of the cold.

For days on end, clouds obscured the view and chill rain drenched us; sometimes wet, driving snow lashed us. Errant currents swirled around us, and rain dimpled the water's surface. We paddled for hours into a fierce, cold head wind until our arms ached. This was not the balmy summer we had expected, and I began to wonder why such delicate creatures as shorebirds would migrate thousands of miles to breed here. As the trip progressed, however, I saw fewer shorebirds than I had expected.

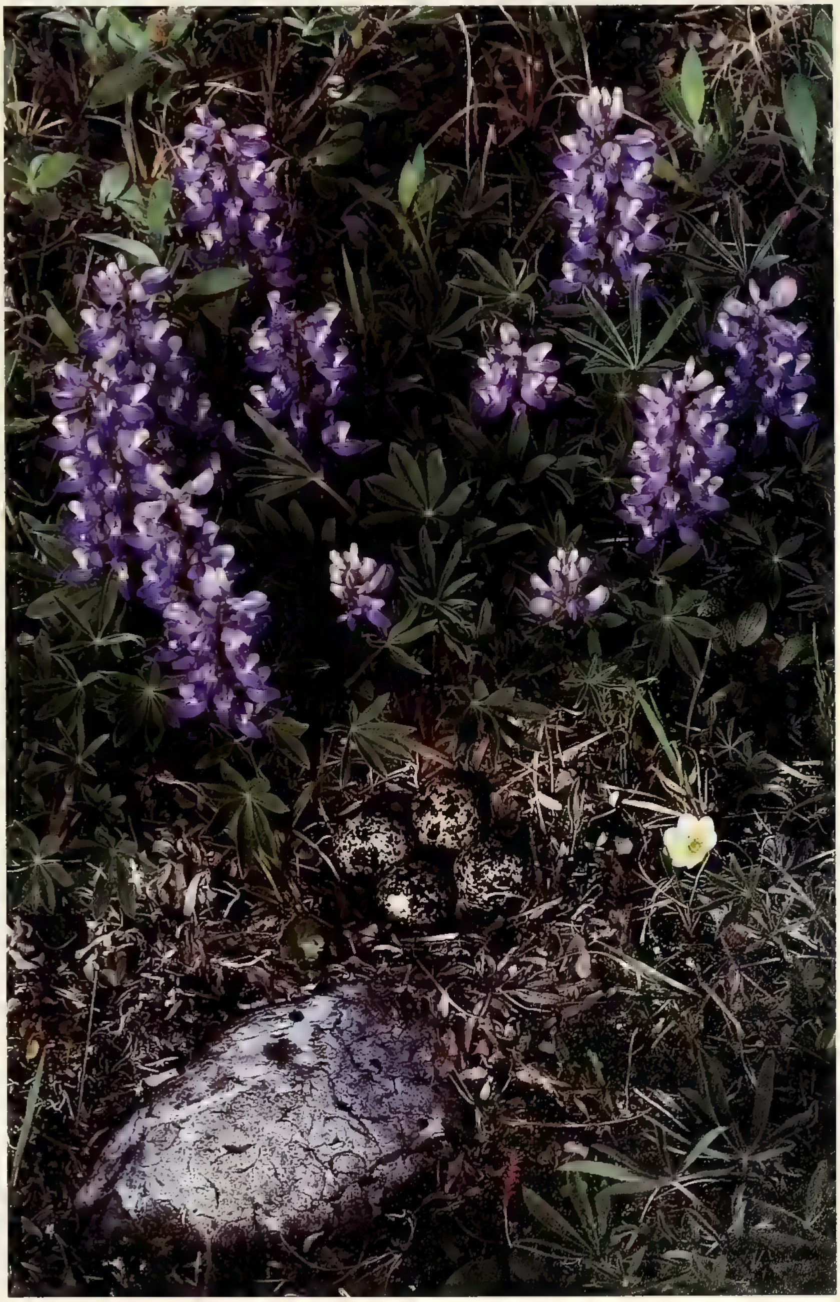
The day after our first long paddle, we stopped at a gravel bar to camp and built a small fire of willow twigs to heat our coffee and warm us. The bar was windswept and mercifully free of mosquitoes. As I was exploring on the gravelly flats, a pair of arctic terns began to divebomb me. Missing my head by inches as they dived, they made clicking sounds like stones banging together. After about ten minutes, I found their nest scrape. In it were two tan eggs, densely covered with rich, chocolate brown spots. The eggs blended perfectly with the multicolored, waterworn pebbles all around them. As I bent over the nest to photograph it, the terns' clicking grew louder. Not only did they hit the back of my head; they also began bombarding me with their droppings. I took one direct hit on the arm, and another narrowly missed my head.

Later, we cooked some of the deep olive, blue-spotted arctic char we had pulled from the river. On our first "night" (at this latitude the summer sun dipped down to the horizon but never set), we were kept awake by the mewgulls, and when we got up we found that they, and not a bear, had eaten the remaining fish that we had planned to have for breakfast. They had, however, missed their chance at a meal of fresh tern eggs nearby.

Having made good time, we stopped for a day near Lake Maturak to fish for lake trout and muskellunge. Walking to the lake, we traversed a soggy, elfin forest of moss and dwarf willows, interwoven with sedges and sprinkled with small, pink *Cassiope* flowers. Suddenly, out of the corner of my eye, I saw what I thought was a mouse silently scampering away over the mossy ground. It dodged under some dwarf willows, but as it emerged on the other side, I realized that it was not a mouse at all, but one of several tiny arctic sandpipers, called a least sandpiper. I knew I had flushed it from its nest. Doubting that I could relocate it by sight alone, I retreated a few paces. Within minutes the sandpiper came back.

A clump of wild lupine provides some shelter for this American golden plover nest.

Michio Hoshino; Minden Pictures



Only the presence of parent birds nearby betrayed the location of this pair of arctic tern eggs in a nest scrape on a gravel bar.
Bernd Heinrich

The guileful art of protecting the tender embryos has been perfected by birds over millions of years.

I saw it crouch down, locating the nest for me. The four cream-colored eggs within it were spotted and blotched a rich reddish brown and blended in with the dead sedge and dwarf willow leaves. I led my nephew to within four feet of the nest, but he was unable to see the eggs until I pointed them out.

Sandpipers and plovers lay clutches of four eggs over a period of about four days. The eggs are exceptionally large compared with most eggs of birds the same size, and they contain a substantial store of food, giving the precocious young a good "running start" as soon as they leave the egg. The clutch of four large eggs weighs more than the bird that laid them. The eggs are pointed at one end so they can fit together in the middle of the small nest, leaving little wasted space beneath the incubating parent.

The delicate hues of these eggs pleased my eye, but I could not imagine them making any difference to the bird. In Europe and Africa, many forest birds recognize the color of their own eggs and keep a sharp eye out for eggs deposited by parasitic birds, such as cowbirds, that do not raise their own young. But tundra nests are easily guarded in the open habitat, and with no parasitic birds around, the shorebirds had no need to learn to recognize strange eggs in order to eject them.

To test whether the birds recognized their own eggs, I removed one from the least sandpiper's nest and replaced it with a white pebble of slightly larger size, then stepped back thirty feet to watch. Within a few minutes the sandpiper came running back, fluffed her belly feathers, and resumed incubation without a moment's hesitation. I placed the purloined egg gently in a tundra pool to see if it was almost ready to hatch. A newly laid egg will sink, but as its reserves are used up by the developing embryo, it becomes considerably lighter as some of the liquid is replaced by gas. This egg floated. I later retrieved my warmed rock from the sandpiper's nest and replaced it with the egg, which was none the worse off for my little experiment.

A week later, farther down the river, I found recently hatched least sandpiper chicks. The tiny wraiths were wrapped in the fluffiest chocolate brown down imaginable. When I picked one up it suddenly went limp and closed its eyes, as if it had died. I put the seemingly lifeless creature back where I had found it and stepped back to watch. It remained there unmoving. But when its parent came back and cheeped, the chick suddenly righted itself and ran off. It had merely been playing possum.

Such bird sightings, and the rivers we passed that run into the swelling Noatak, continued to mark our progress. Near Atangora Creek, which we called Char Creek because of the many fish we caught there, I spied a semipalmated plover. Apparently, it had spied me first, for it was doing a broken-wing display to lead me away from its nest. I knew a nest was nearby but had no idea where it might be. After fifteen minutes, however, I located the nest scrape in the middle of a large patch of bare gravel. The four pale olive eggs were heavily blotched with black and dark brown spots. When I tested them in water, the eggs floated high—they were also within a day or two of hatching.

We made it to the Cutler River the next day and marveled at its clear waters mixing with those of the turbid Noatak. On the surrounding tundra, I found an American golden plover. Had it left its nest because it saw me approaching? I watched it with binoculars for an hour, and saw it settle down several times. Each time I was fooled by the bird, and I found nothing. Finally I gave up. Diverted by a bald eagle near the river, I picked my way among lichen-covered stones, sedges, and creeping arctic willows. Here, I stumbled by accident onto what I had been diligently searching for: four black-spotted and blotched plover eggs with a faint olive undertone. Before two months were up, the contents of these eggs would be adult birds that would fly across the North American continent, down the Atlantic coast, and across the Caribbean to northern South America. Then they would fly across the Amazon to spend the arctic winter in Argentina, Patagonia, or Tierra del Fuego, the southern tip of South America. In the spring, they would return to the Noatak, completing a round trip of more than 20,000 miles.

In some 200 miles of paddling, we had seen wolves only twice. We encountered the first as we rounded a bend of the river. A tall, rangy beast, it had been wading in the shallow water near the edge. Walking nonchalantly to the side, it shook its black pelt, throwing up a spray of water, then bounded up over the bank and out of sight. Later, on a rare, sunny day, we saw two more wolves. Both were grayish brown, and one had been lying down in the water. They, too, bounded up over the bank as our canoes drifted near. Occasionally, arctic foxes patrolled along the river edge.

Where the river had carved away hillsides to form cliff faces, we saw nests of rough-legged hawks and occasionally the guano-marked nesting shelves of peregrines and gyrfalcons. We saw a golden eagle's aerie on a cliff top, and some nests of Say's phoebes near the bottom. The peregrines chattered defensively because they had small young. Raven young were just leaving their nests; one nest on a cliff fifteen feet above the water had three fully feathered young.

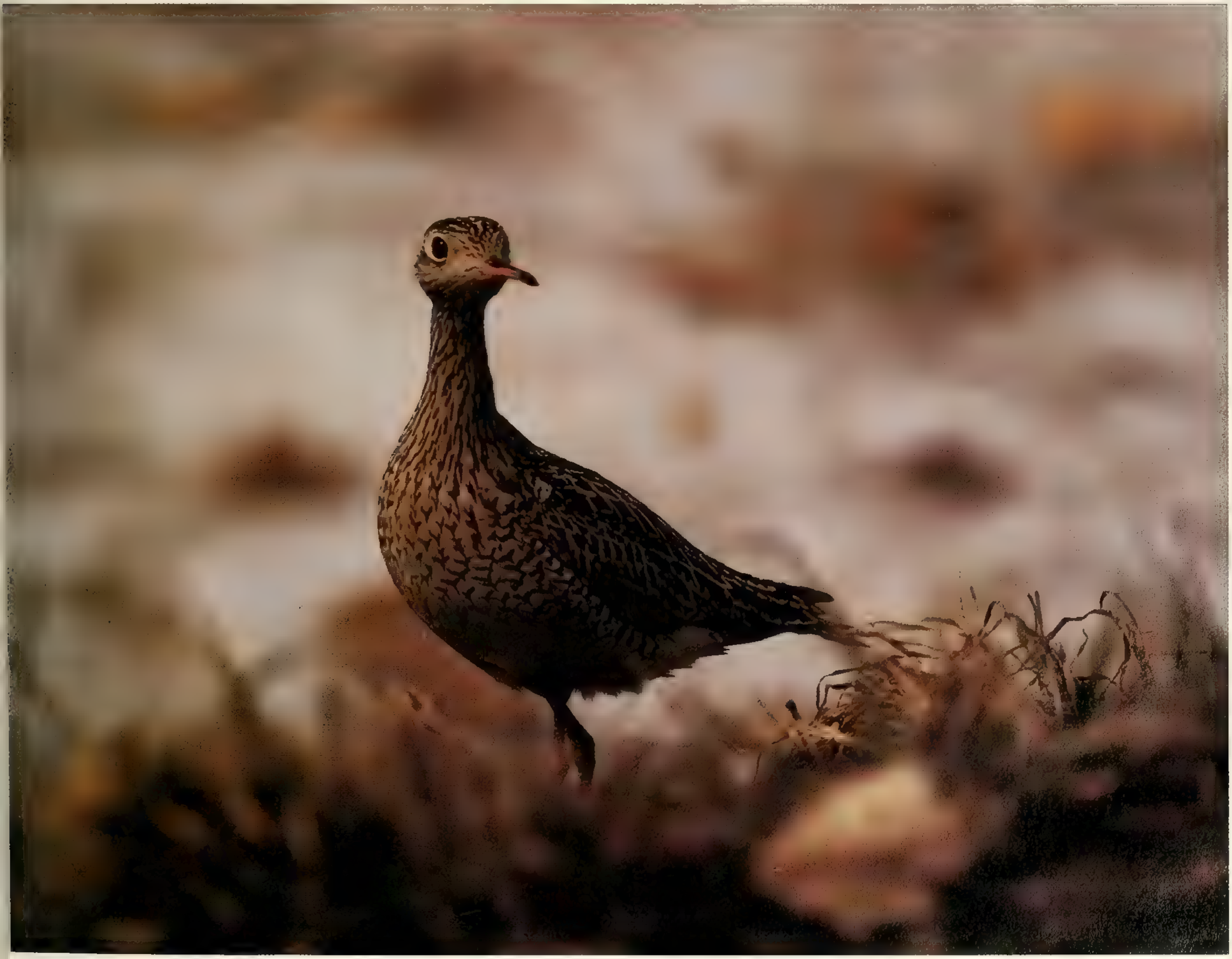
After a little more than a week, we had reached our halfway point at the Nimiuptuk River. The tundra here was ablaze with pink, bell-like andromeda flowers; yellow arctic poppies; and small, delicate blue forget-me-nots with yellow centers. I counted thirty different kinds of flowers. Here we also saw the first human habitation on the river: an unoccupied hunting cabin built by a man named Abe Howarth. It had traps hanging all around it on the outside; inside there was a dried fox pelt and a picture of Jesus. A dead raven lay behind a small shed. We made ourselves at home, and while one of my friends stirred a batch of pancake mix in a large bowl cradled between his legs, we watched a red-backed vole forage for cracker crumbs on the table. We also continued to feast on the one large (thirty-three inch), indescribably delicious arctic char we had caught earlier at the mouth of the Cutler River. During its migration upriver, a char's back turns steel gray and its belly silver. Delicate pink spots adorn its sides.

Other travelers had also stopped at Abe's cabin and left letters of thanks. "Dear Abraham," one said, "Thanks for the use of the cabin. We were up until midnight the night before, cleaning two moose in the rain. After pitching camp in the dark and rain, using the cabin to dry, cook, and rest was heaven." We, too, left the cabin refreshed and warmed.

As we continued on to the entrance to the Noatak canyon, the current grew increasingly swift and more powerful. Bones of caribou had been washed ashore. We had had our own close call earlier, when I had misjudged the current at "the suckhole." Here the river slammed into a sheer cliff, and the whitecaps that had looked

Its nest nearby, an upland sandpiper surveys the tundra.

Robert P. Carr; Bruce Coleman, Inc.



As it wanders , a Baird's sandpiper chick blends in well with the surrounding flowers and vegetation.
Jan Van de Kam

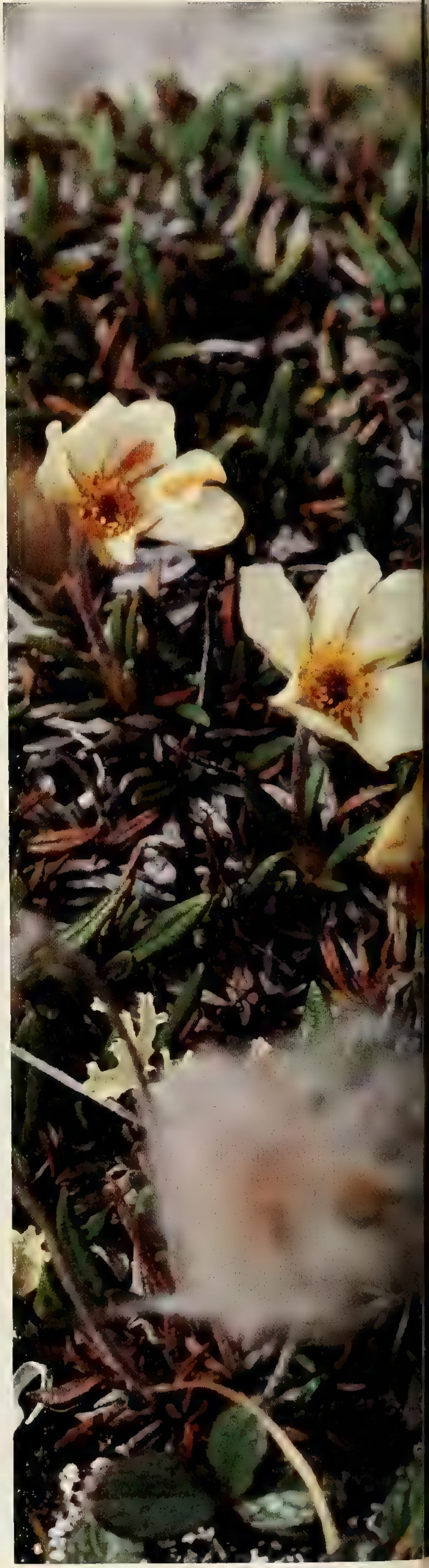
Just as it was time to leave, against all odds, I stumbled upon the nest.

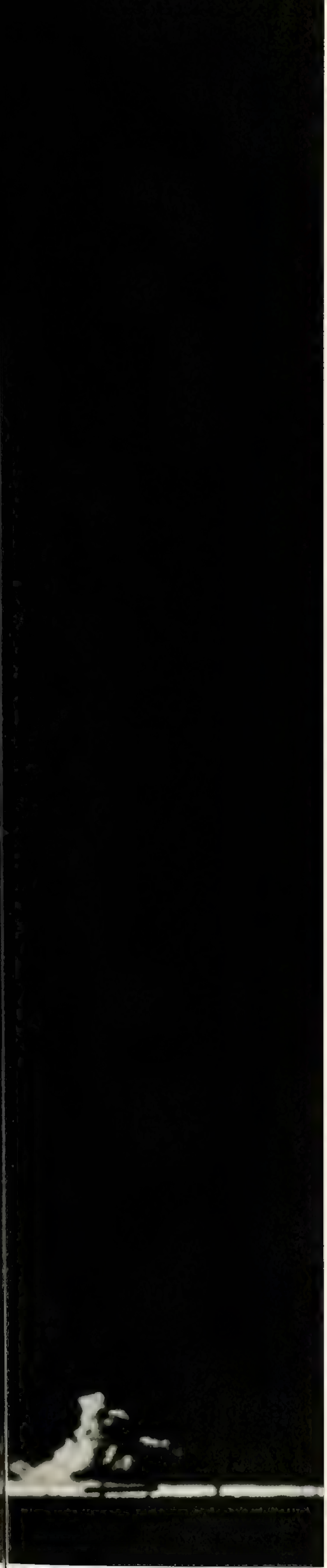
manageable from a hundred yards suddenly loomed like raging monsters as they engulfed us. I saw my nephew's terror-stricken face for just a second and thought it would be the last time I saw him, or anybody else! We capsized, but miraculously we were both soon bobbing at the surface, and a half mile farther we made it to shore to join the others. Having witnessed our mishap, they had hugged the inside bank and avoided the main current and were waiting with our retrieved canoe.

Camping in a cold drizzle at the head of the Noatak canyon, we saw patches of snow on the nearby hills. Here we also saw the first small spruce trees, which would become more numerous as we approached the coast. We heard a bird sing that we had not heard before. It sang while flying, and we called it the wolf-whistle bird. The song began with a twitter, followed by a slow, low-pitched, mournful wolf-whistling trill that rose higher and then descended the scale. I knew it was a shorebird when I saw its long bill. Where might this one have its eggs? To find a nest on this trackless tundra would be difficult. On the seemingly uniform tundra, you might search one small plot systematically, but how would you know you were not searching parts of the same plot over and over again or leaving large gaps of unexplored ground?

While the rest of the crew went fishing, I set out to find one last bird nest. I kept hearing the haunting song of what I later determined was an upland sandpiper; that his mate was nearby, sitting on her eggs, was continually on my mind. However, after a few futile sweeps back and forth across the tundra, I settled down to watch bumblebees. Just as it was time to leave, against all odds, I stumbled upon the nest. The four eggs were different from any I had found so far. The nest—set in the moss, lichen, and sedge—held the rich, cream-colored eggs, blotched delicately in pale lilac and light chocolate with a sprinkling of dark brown, nearly black dots. I felt the warmth of the eggs and realized that the bird had left without my having seen her. Although many shorebirds (the killdeer from New England, for example) often feign a broken wing when surprised near the nest, this female had chosen not to use this tactic.

Perhaps some predators here, such as wolves, have learned that this display is a sign of an easy meal. It appeared to me that while in the forests of New England, each bird can hide its nest in a unique spot to foil predators, here it was not the nest site that differed, but the birds' evasive maneuvers to distract predators from their nests. In both cases, the birds have evolved strategies that counter the learning capacities of egg thieves. I was elated to take my sixth and final trophy, a picture of a rare find. Then I rejoined my friends, and we again flowed with the river on its way to the Chukchi Sea. ☐





Known as Trinity, from the code name for the detonation site, the first atomic explosion was the culmination of a three-year crash project.
Los Alamos National Laboratories

Ground Zero Revisited

Fifty years ago in a desert, humans left the mark of a new age

by Daniel J. Lenihan

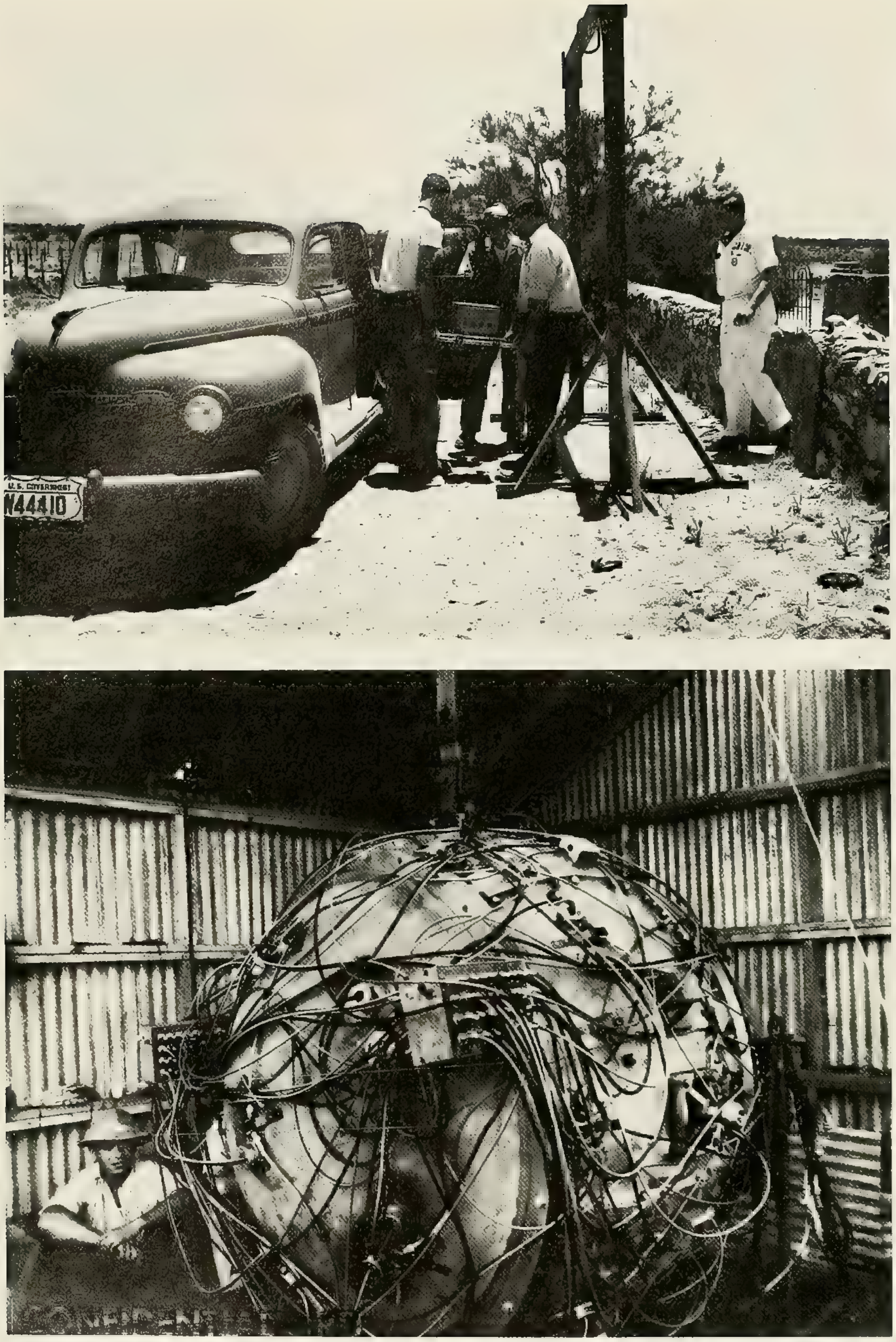
Just before dawn on July 16, 1945, in a forbidding stretch of central New Mexico desert that the conquistadors had cheerily dubbed Jornada del Muerto (journey of death), a motley crowd of men worked feverishly to detonate the first atomic bomb. Some were clad in severe military dress; others sported more casual, civilian apparel. The hum of conversation and the din of motors mixed with the distinctive chirps of spadefoot toads, drawn forth by a light sprinkling of rain. Larger creatures, which might have disrupted the miles of electric cable strewn in the desert, had already been eradicated. Cattle ranchers had been induced or harassed into removing their stock, and pronghorn antelopes, the fastest land animals in the New World, had not been able to elude the 50-caliber tracer bullets fired from vehicle-mounted machine guns. Snakes and centipedes wisely kept their heads down.

At 5:29:45 A.M., Mountain War Time, an atomic chain reaction lasting less than one-millionth of a second unleashed a force equivalent to nearly 20,000 tons of TNT. The desert lit up with a flash visible more than a hundred miles away as the hundred-foot-high steel tower supporting the bomb vaporized and disappeared into a fireball. In minutes a cloud mushroomed to 40,000 feet. The blast was immortalized in motion pictures and still photos, but only narrative descriptions remain to help preserve memory of the sound: The bomb's shock wave blew out all the sound recording systems.

"As though awakened from a fantastic nightmare," recorded one observer watching from one of the blast-proof bunkers, "we all jumped to our feet and started cheering. We had succeeded, and we cheered. We cheered and gradually fell silent as the meaning of our success became certain." J. Robert Oppenheimer, lead scientist of the project, is said to have echoed a line from the Bhagavad-Gita, a sacred Hindu text: "I am become Death, the destroyer of worlds." A more prosaic comment came from one of the military men: "The longhairs have let it get away from them."

> We had succeeded, said an observer. We cheered and gradually fell silent as the meaning of our success became certain.

Four miles away from ground zero, twenty mice hung by their tails from a fence post, where a security officer had placed them the previous day. They constituted the first empirical attempt to monitor the effects of nuclear radiation from an atomic weapon. All the mice were dead, but not from the bomb. They died of thirst, as would most creatures hung out to dry in the Jornada, where every steer is allotted a full square mile for grazing.



The plutonium core arrives at the blast site, top. To allow heat to escape, holes were drilled in the box containing the radioactive material. Bottom: The assembled Trinity device was housed in a shed atop a 100-foot steel tower.

Photographs from Los Alamos National Laboratories

Some cattle and deer received radiation burns, and an untold number of tarantulas and spadefoot toads were vaporized, but there were no human casualties, except for one person who looked at the flash and temporarily damaged his eyes. A carefully concocted cover story about an ammunition dump exploding was released to the public to allay the suspicions of any distant witnesses to the event. A statement issued by Col. William O. Eareckson, the commandant of the Alamogordo air base reservation, commented that "weather conditions affecting the content of gas shells exploded by the blast may make it desirable for the Army to evacuate temporarily a few civilians from their homes." The cover story held, but a batch of Kodak film that developed a fogging problem was later noticed by some irate consumers. It seems the film's packing material contained chaff that originated in an Indiana wheat field that received a chance deposit of fallout from the blast.

Known as the "gadget," the experimental device was a sphere five feet in diameter lacking an aerodynamic bomb casing. Within the sphere was a special arrangement of high explosives, designed to violently—but precisely—compress a mass of plutonium and so create an explosive chain reaction. Plutonium atoms sometimes decay, releasing neutrons and energy. In a chain reaction, released neutrons strike the nuclei of nearby plutonium atoms and cause them to fission, or break apart, releasing more neutrons and energy, and so on. For the process to result in a nuclear explosion, a certain critical concentration of plutonium must be brought about instantaneously.

Criticality can be achieved by increasing mass (adding more plutonium) or—as at Jornada del Muerto—by compressing a barely subcritical mass to increase its density. The men toiling in the desert knew that if the plutonium was not compressed evenly and with great force, it might blow apart without releasing much of its potential energy. The plutonium mass (reportedly softball size) comprised two joined hemispheres with a hollowed-out center. The hollow accommodated a ping-pong-ball-size lump of beryllium and polonium, substances that emit neutrons at a high rate. Placed in the center of the sphere, this "initiator" helped insure the efficiency of the reaction.

The blast site, code named Trinity, lay 200 miles from Los Alamos, the secret installation where the bomb was designed. Named after the Los Alamos Ranch School (itself named after the local cottonwood trees), Los Alamos became the focal point of the weapons project, owing partly to Oppenheimer's fondness for the area. Oppie, as he came to be widely known, had often stated that "my two great loves are physics and New Mexico. It's a pity they can't be combined." Officially, Los Alamos didn't exist, so nearby Santa Fe was the contact point for the outside world. Some children born to parents working at Los Alamos have a post office box number in Santa Fe listed as their official birthplace.

As the time drew near for the test and the anticipated strategic use of the weapons to follow, extraordinary measures were taken to convey to Los Alamos minute quantities of plutonium, as well as uranium 235. (This rare form of uranium was the basis for a second type of bomb, which employed a simpler technology: a sawed-off gun tube was designed to shoot two pieces of uranium together, achieving riticality by increasing mass rather than lensity.) A bargain at several million dol-ars an ounce, the radioactive elements far outstripped the market value of other pre-ious substances. Santa Fe and the even leepier one-horse railroad town of Lamy ecame the scene of an unlikely series of loak-and-dagger efforts, as couriers with ead-lined briefcases arrived almost daily rom Oak Ridge, Tennessee, and Hanford, Vashington.

All the secrecy led to unanticipated roblems. One night in May, when prepa-ations were at fever pitch, two B-29s on a raining mission out of Alamogordo mis-ook the lights at the Trinity base camp for heir bombing target. They dutifully pep-ered the camp with 200-pound dummy ombs filled with five-pound explosive harges. Several outbuildings were dam-ged, including the Trinity carpentry shop nd stables. Fortunately there were no in-uries, just red faces and black marks in everal career folders.

> A batch of Kodak film that developed a fogging problem was noticed by some irate consumers. It seems the film's packing material contained chaff that originated in an Indiana wheat field that received a chance deposit of fallout from the blast.

One of the fully authorized observers at the event was a man who later caused a security nightmare. Klaus Fuchs, a physicist in the project's T (theory) division, did not share the secrets of the bomb with the Germans or Japanese, the enemies of the United States, but with an ally, the Soviet Union. He and a GI named David Greenglass later drew long prison sentences for treason, and a married couple, Julius and Ethel Rosenberg, eventually died in the electric chair, convicted of playing a role in the affair.

The effort to build the atomic bomb was a watershed in scientific endeavors, becoming the model for "big science" projects down to the present day. A scholarly civilian cadre rich in theoretical acumen, including several Nobel Prize-winning scientists, was organized within a unique mission-oriented, military framework. The group included the cream of American and European physicists, some of whom had escaped from the threat of Nazi

nrico Fermi, one of the scientists on the Los Alamos team, shared magic tricks with his colleagues. Fermi ad earned a Nobel Prize for his work on controlled nuclear reactions.

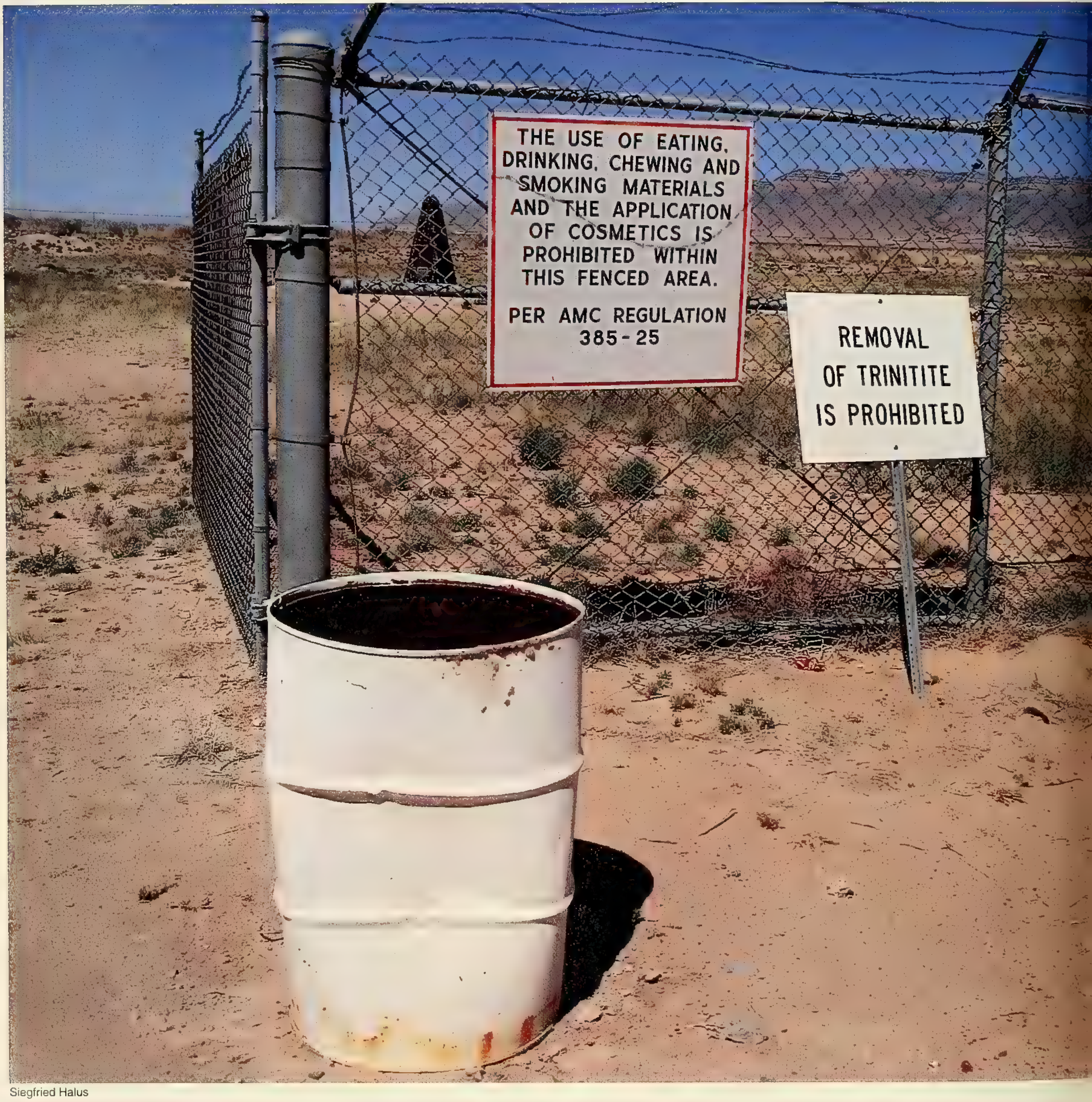
s Alamos National Laboratories

concentration camps. There were also GIs, military police, and engineers (in project lingo, "plumbers"), and their families. Members of the counter-intelligence corps—affectionately known as "creeps"—watched over the supersecret project, even following personnel on short shopping trips to Santa Fe.

The U. S. Army Corps of Engineers was assigned the lead role in the atomic bomb enterprise, and the project was given a name with which this particular government bureaucracy could cope. The corps, which engages in huge engineering and public works programs, divides itself into districts. Consequently, a district was created to encompass the project. The original office was set up in the Borough of Manhattan in New York City, so the district came to be called the Manhattan Engineer District, or MED for short. The building of the atomic bomb would be remembered in the history books as the Manhattan Project.

The longhairs, plumbers, and creeps of Los Alamos may not have been playing dice with the universe but they were definitely shooting craps with nature. New ground was being broken, and the enterprise was fraught with peril. At one site called Omega they "tickled the dragon's tail" by dropping increasingly larger subcritical balls of plutonium and uranium through rings of similar material to see ex-

The seeming effortlessness of nuclear weapons was what was so psychologically devastating. One plane, one city.


THE USE OF EATING, DRINKING, CHEWING AND SMOKING MATERIALS AND THE APPLICATION OF COSMETICS IS PROHIBITED WITHIN THIS FENCED AREA.
PER AMC REGULATION 385-25
REMOVAL OF TRINITITE IS PROHIBITED

Siegfried Halus

actly how much was needed to start a hain reaction. Hopefully, gravity would lear the ball through the ring before the ragon bit them. (While there were no eadly accidents before the war's end, in 945 and 1946 two men died in criticality xperiments.)

Within twenty-four days of the Trinity est, more than 200,000 Japanese civilians ost their lives or were severely wounded t Hiroshima and Nagasaki. For some, debilitating side effects from radiation would how up years later. A uranium-based omb—previously untested, both because he scientists were more confident it ould work and because the main ingredient was in short supply—was used in the drop on Hiroshima on August 6. A plutonium-based implosion device identical to the one tested at Trinity served to level most of Nagasaki on August 9. Five days later Japan surrendered.

It wasn't the sheer number of civilian casualties that so shocked the senses. Using hundreds of B-29s the allies were already conducting massive conventional bombing operations over Japanese industrial and population centers. The March 9 bombing of Tokyo, for example, killed an estimated 100,000 people. In the European theater, Dresden had been firebombed almost to oblivion, immolating 35,000 of its inhabitants. The seeming effortlessness of nuclear weapons was what was so psychologically devastating. One plane, one city.

For the war-weary American public, which had seen heavy losses at Okinawa and grimly anticipated a protracted invasion of the Japanese homeland, the bomb was a godsend. One may debate the number of lives lost and saved on either side, and argue moral issues of means and ends. But to any American fighting man returning from the European front only to repack his bags for the push into Japan, the salient point was that the bombing may have saved his life.

There were other, less public reasons for using the new atomic weapons to hasten the war's end. The Soviet Union was about to enter the war against Japan and would no doubt partake heavily in the victor's spoils if the occupation efforts drew into a long campaign of attrition. In addition, from a purely bureaucratic point of view, there was a need to vindicate the incredible expense of the Manhattan Project. What would the reaction have been, at a time when pennies were actually worth something, if the American people had learned that $2 billion had been spent with no specific congressional authority on the making of a weapon that was never used?

Some suspect that Hiroshima and Nagasaki were bombed, in part, to put the fear of God (and, coincidentally, the United States) into the Soviets. Even Stalin, who already knew through Klaus Fuchs that the atomic bomb was viable, was stunned by the demonstration of the bomb's raw power. Within a year of Japan's surrender, two more offspring of Trinity were detonated at Bikini Atoll in the Marshall Islands, purportedly to measure the effectiveness of the weapons against naval forces (see "Pacific Requiem," *Natural History,* August 1994). Humanity quickly graduated to an era in which the Trinity device would be barely adequate to trigger a hydrogen bomb, a fusion device that releases the power found in the sun and stars. Most Americans of my baby boom generation have vivid memories of hiding under their desks at school, waiting for all-clear signals. More than forty years of white-knuckle nuclear brinkmanship may have finally taught us that the only thing worse than a belligerent

Located within the White Sands missile range, the Trinity site, left, is now open to tourists on a limited basis. Visitors are not permitted to collect fragments of trinitite, above, the glassy substance created when the nuclear fireball melted the desert sand.

Jim Bones

TRINITY SITE
WHERE
THE WORLD'S FIRST
NUCLEAR DEVICE
WAS EXPLODED ON
JULY 16 1945

What would the reaction have been, at a time when pennies were actually worth something, if the American people had learned that $2 billion had been spent with no specific congressional authority on the making of a weapon that was never used?

iemy is a frightened belligerent enemy.

On Thanksgiving Day 1994, my friend m Sprinkle, a longhair from Los lamos, shared with me an album of phos and a story. Working as a consultant in azakhstan, he had befriended a one-time GB agent, now the security officer of a rmerly secret city where nuclear eapons had been developed and tested. oth men quietly acknowledged the irony history that had brought them together confront the problems of cleaning up iclear waste and converting plutonium id uranium production to peaceful use. ome of the potential weapons material om Kazakhstan is being readied for shipent to Oak Ridge, Tennessee, for safeeping.

Jim gave the man a parting gift, a briefise inscribed with the words "Los lamos National Laboratories." This is a eeper as collectors' items go among the GB set. Not to be outdone, the former gent presented Jim with a sheaf of photos he boarded the plane. On the way home New Mexico, he pulled them out of the own paper wrapper. The first was a picre of an atomic bomb blast that seemed iguely familiar: a mushroom cloud, a small fleet of ships. Only this couldn't be Bikini Atoll because there was an ice field clearly visible in the background. It was the Soviet version of Bikini, conducted somewhere in the Arctic Ocean.

The next photo was also of an atomic blast, this one strangely menacing. Huge, raw, black plumes of smoke and dirt were rising thousands of feet in the air, over some Siberian Jornada del Muerto. He didn't need to wait for American intelligence officers to identify this picture. What he was holding in his hand was a photograph of the first Soviet atomic bomb, the USSR's Trinity blast.

It takes me only three hours to drive from my home in Santa Fe to the Trinity site in the White Sands missile range. South of Santa Fe, signs warn of construction delays on state highway 285. This lightly traveled, two-lane road is being widened to accommodate a new form of containerized freight. Drums of radioactive waste will soon be shipped to the Waste Isolation Pilot Project at Carlsbad, New Mexico. The half-life of plutonium may be considerably longer than that of the sociopolitical entities that create it.

These days at Trinity, the pronghorn

small monument marks ground zero, left. Above: A view out of one end of Jumbo 214-ton steel containment vessel built to salvage plutonium in case the bomb zled) reveals a refreshment stand set up at Trinity. Jumbo was never used. The ds were blown off by the Army in 1946 using eight 500-pound bombs.

otographs by Jim Bones

Courtesy of Jim Sprinkle

The Soviet Union's first successful nuclear test, above, took place in 1949. Opposite page: In May 1943, an accident during the development of an experimental bat bomb resulted in the destruction of a new Air Force base in Carlsbad, New Mexico.

and coyote, along with an influx of feral horses, have recaptured the Jornada. The site also sees an increasing number of oryx, an exotic African antelope brought in by the state to provide trophies for hunters. (Rangers at the neighboring White Sands National Monument are less than thrilled with the oryx because they trample archeological sites and tend to attack visitors.) The only large piece of hardware of interest is the hulk of Jumbo, a steel housing built for the Trinity blast. It was meant to contain the valuable plutonium for salvage, in case the bomb fizzled. In the end, Jumbo was discarded as an unnecessary and perhaps risky complication.

At ground zero I am impressed with how nondescript the area is. A black stone monument marks "where the world's first nuclear device was exploded." It is just flatter and smoother here than the desert that surrounds it. Stooping at the blast depression (not really a crater), I run my hands through the sand and find pieces of trinitite, a new substance that was created from the superheating of desert sands by the fireball. The whitish green ceramic nodules lie about like freakish jewels.

When attempts were made in the early 1950s to have the Trinity site declared a national monument, the Park Service requested that a hundred pounds of trinitite be sent to its regional office in Santa Fe. This was to insure there would be plenty left to put on display in a proposed visitor center, given that souvenir hunters were making off with the rare material. One of the reported uses for the pilfered nodules was the making of necklaces; presumably they did wonders for overactive thyroids. It still bothers me a bit that no one recalls whether the hundred pounds of trinitite was given to the Park Service for storage, because I happen to work in the service's Santa Fe office.

The envisioned Atomic Bomb National Monument never materialized. None wa even considered for another top secre weapon tested at Carlsbad, not far fron the Jornada del Muerto. Unlike the atomi bomb, which was originally intended fo use against the Nazis, from the onset th target for this device was the Pacific theater. The hope was that it would level key cities in the Japanese Empire and demoralize the Japanese citizenry, forcing them to surrender.

He didn't need to wait for American intelligence officers to identify this picture. He had in his hand a photograph of the first Soviet atomic bomb, the USSR's Trinity blast.

This, too, was a bomb, roughly half the size of the atomic bomb, to be dropped by parachute to slow the fall. At the assigned altitude the payload would be released and flutter away in all directions. The payload was hundreds of Mexican free-tailed bats the same creatures that each evening pou like smoke from Carlsbad Caverns and head south to their insect hunting grounds Each bat would carry a small incendiary charge, which would activate about an hour later. Deployed just before dawn, the kamikaze bats would have just enough time to fly to their favored roosts in the rafters and roofs of buildings.

That the bat bomb was a potentially devastating weapon was amply demonstrated one day in May 1943, when the commander of a new Air Force base in Carlsbad was forced to evacuate his post to allow a group of scientists to work in privacy on the new secret weapon. While several of the fully armed incendiary bats were being photographed, they escaped their containment. The diminutive animals flew off to roost deep in the recesses of the newly constructed buildings and, in short order, burned the entire facility to the ground.

The longhairs had let another one ge away from them. □

Elephant Raiders and Rogues

The more Asian elephants raid crop fields, the more the farmers' traditional tolerance is put to the test

by Raman Sukumar

In Assam, India, an Asian elephant is enveloped in a dust cloud of its own making.
Gerald Cubitt

> When new settlements arise in river valleys that elephants have used for millennia, conflict is inevitable.

Darkness engulfed the natural amphitheater of Hasanur village, nestled picturesquely amid the lush green Biligirirangan hills of southern India, as I drove out from my camp for a rendezvous with two bull elephants that had been raiding local crop fields. It was July 7, 1981. During this time of year—the southwest monsoon season, when rainfall is sparse—not many farmers cultivate crops, leaving the bulls with a limited choice of fields for their nocturnal excursions and thus making it easy for me to find them.

As I neared a farm close to the jungle and scanned the maize field with a spotlight fitted to my jeep, I made out two dark shapes rising above the ripening plants. Tusks gleamed softly as the elephants turned toward the light. One, a little smaller than the other, quickly turned back and faded into the darkness. The larger bull stood his ground for a while, then ambled back a short distance to the farm boundary, where he fed sporadically on grass, ignoring our battery of lights and the shouts of the farm laborers attempting to drive the marauders away.

This bull, its left tusk shorter than its right one, was familiar to me. During the month of April, I had seen him regularly at Karapallam pond, five miles to the north. For the next hour and a half, I watched him as he worked his way through the fields. Then I returned to my camp. Soon after I departed, he rushed at the laborers, who were forced to seek refuge inside a building for the rest of the night.

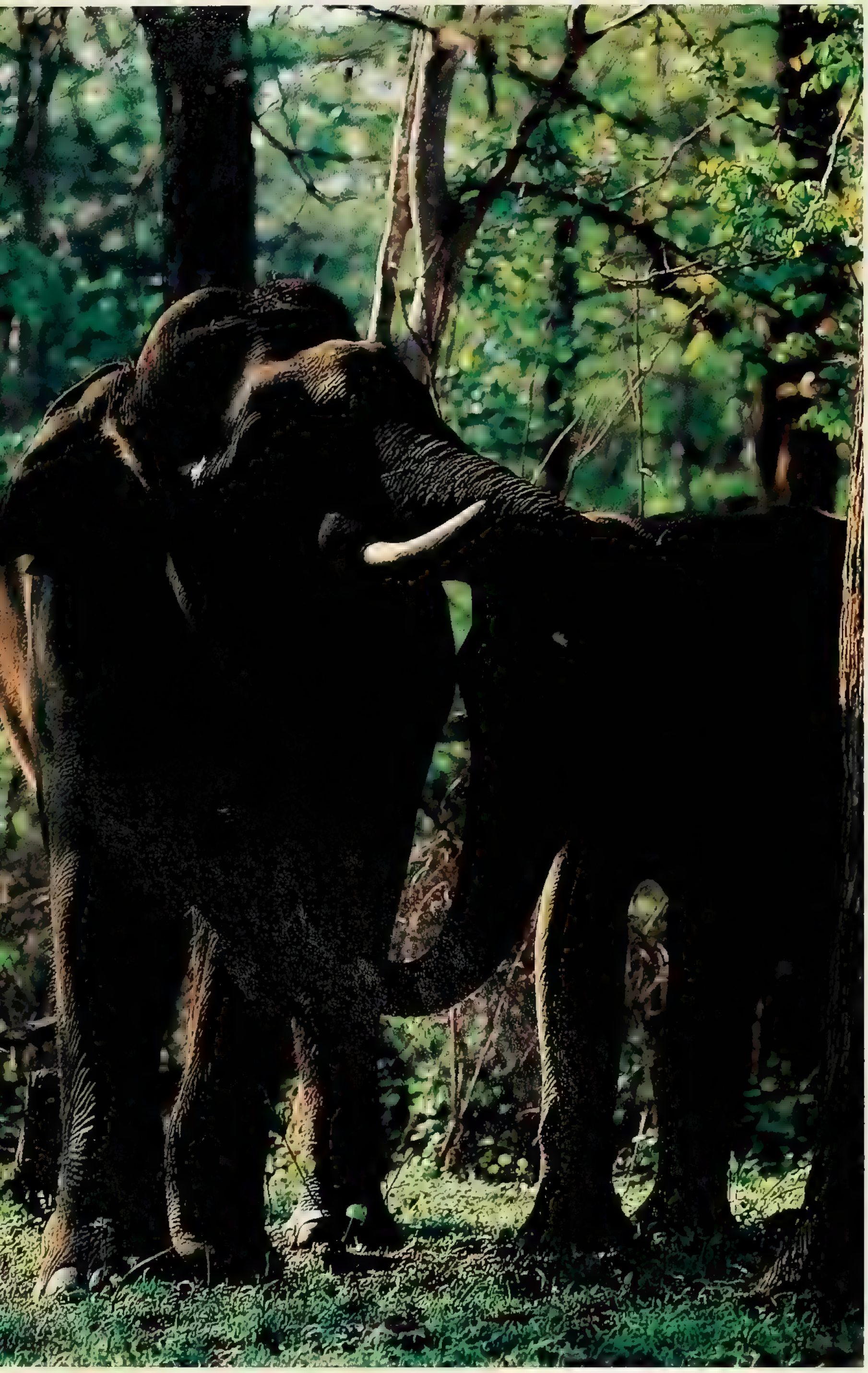
A few months later, in early November, Hasanur was a sea of ragi (finger millet), watered by the heavy northeast monsoon rains. Ever since the ragi had begun flowering in October, bull elephants had been feasting on this staple food crop. Up to six bulls were coming into the area at night. Hasanur's most persistent and destructive marauder was undoubtedly Vinay, a large bull easily recognized by his short right tusk, which was broken off near the lip.

On the night of November 3, my tracker Setty and I waded through the ragi fields to a treetop platform, where we spent the night watching Vinay systematically pulling out the succulent plants with his trunk, biting off the flowering shoots, and discarding the stems and roots. For two hours, the farmer whose fields were being

Only male Asian elephants have tusks. Adult males live on their own or with other bulls for most of the year, congregating with family groups (females and immature males) primarily when they are in musth, a period of intensified sexual interest.

Raman Sukumar

The stakes are high for males in the elephant mating game, and bulls may be willing to take risks to increase their chances of mating.



In India's Nagarahole National Park, a cow sniffs a bull in musth, when males secrete fluids from their temporal glands and dribble urine. Elephants living within park boundaries are less likely to become crop raiders than are those whose habitats abut fields.

Jean-Pierre Zwaenepoel

demolished tried to chase Vinay away; he and his men shouted and shined their flashlights at him but it was all in vain. Vinay's calm behavior surprised me, for he was an aggressive bull that had, in the past, charged farmers, stuck his single tusk through the mud wall of a hut, pulled down thatched structures, and even killed a man.

Vinay left abruptly just before dawn, a barrel-shaped mass engorged with about 550 pounds of millet. With such a bellyful, the elephant would not need to feed much in the forest during the day. With the coming of night, however, as his appetite returned, he would head back to Hasanur, as he did for about 120 nights that year.

Elephants probably first began raiding crops shortly after farmers started planting them in traditional elephant habitat. The Gajasastra, ancient Indian elephant lore dating back perhaps 2,500 years, tells of wild elephants ravaging agricultural fields in a kingdom that is now part of the northern state of Bihar. As agriculture expanded and human settlements grew, the problem of elephant–human conflict intensified; in general, the problem diminished only in local areas from which the elephant was eliminated. Currently, farmers across Asia, and Africa as well, lose millions of dollars' worth of crops each year to elephants. Many human lives are also lost when the elephants come into settlements.

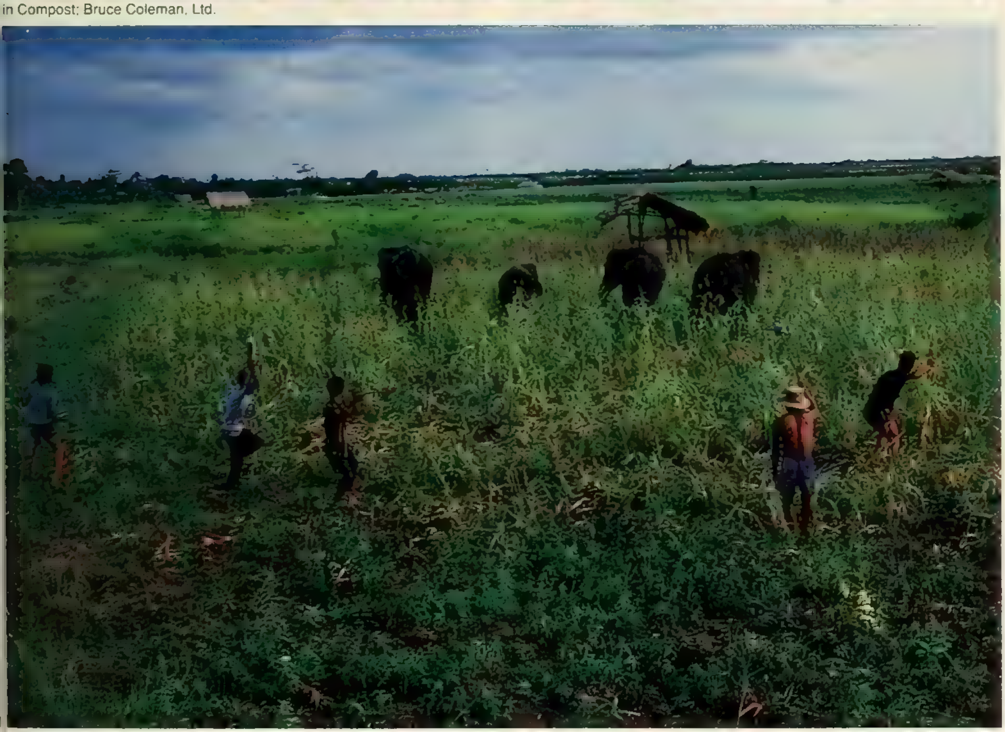
The elephants, of course, are also suffering. Traditionally, Indian farmers tolerate, even revere, elephants and are reluctant to harm them. As the problem worsens, however, and farmers see their livelihoods, and even their lives, threatened, they sometimes trade in their flashlights for guns. Efforts to save the elephant thus require the cooperation of local people who now share its habitat, and such cooperation is possible only if the impact of the elephants on humans and their crops can be minimized.

In an effort to contribute to this effort, I set out in 1980 to answer the fundamental question, Why do elephants raid crops? At the time I began my work, several popular explanations were floating about, including degradation of habitat, competition for water and vegetation, and severing of traditional migration routes. All these factors are undeniably important, for when new settlements arise in river valleys that elephants have used for millennia, conflict is bound to arise. Elephants would naturally consider newly cultivated tracts as part of their original home range. And if habitats become denuded of vegetation as a result of human activities, the elephants are forced to turn to cultivated land to satisfy part of their enormous appetites. Sometimes, simply to quench their thirst, the elephants must cross cultivated enclaves en route to a nearby lake or pond.

These explanations, however, cannot be the whole story, for some of the marauders live amid an apparent surfeit of natural resources. Some seem to consider human settlements their second home, even when they appear to have plenty of room elsewhere. To gain some insight into these puzzles, I decided to take a closer look at just what the elephants were eating. I analyzed both cultivated crops and wild plants and found that cultivated crops, such as cereals and millets, had twice as much protein as the wild grasses available to elephants during the same season. They had even higher levels of minerals, such as calcium and sodium. This finding was not surprising—after all, humans have selected these plants for their superior nutritional qualities.

Cultivated crops—such as succulent millet and sweet sugar cane—are also more palatable man Sukumar

in Compost; Bruce Coleman, Ltd.



Some farmers erect towers in their fields, top, to keep watch for elephants at night. Once a raid begins, as in this cornfield in Sumatra, bottom, there is little farmers can do but make noise and try—often without success—to chase the marauders away.

Farmers across Asia and Africa lose millions of dollars' worth of crops each year to elephants. Many human lives are also lost.

an wild grasses, which become coarse and rasive after a few months' growth during the ny season. Developing a taste for such nutri-us fare would potentially benefit an elephant evolutionary terms: the better the diet, the althier the animal; the healthier the animal, the re likely it will be to reproduce successfully d pass along copies of its genes (including me, perhaps, for selecting nutritious food) to ure generations.

All elephants would thus potentially profit by ding cultivated crops to their diet, but not all phants are equally likely to do so. Some of the elephants in my study visited fields regularly; others rarely or never at all. Within a few months of starting my research, I realized that male elephants were more persistent raiders than females and that, although the bulls made up only 7 percent of my study population, they caused disproportionately greater damage. Much of the explanation lies in elephant social structure, which is organized around matriarchal families consisting of one or more adult females and their female and immature male offspring. Within families, the decision to raid or not to raid is probably made by the matriarch (generally the oldest fe-

The wild population of Asian elephants is only 36,000 to 50,000 individuals—10 percent that of the African elephant.

Decline of a Giant

The total population of the Asian elephant (*Elephas maximus*) is less than 10 percent that of the African elephant (*Loxodonta africana*), yet the latter has received far more attention in international conservation circles. The Asian elephant is still widespread in the tropical forests of south and southeastern Asia, but its total population in the wild is estimated to be only 36,000 to 50,000 individuals dispersed through thirteen countries: India (20,000 to 24,000), Bhutan (60 to 150), Bangladesh (200 to 350), Myanmar, or Burma (5,000 to 6,000), Thailand (1,300 to 2,000), China (150 to 300), Laos (2,000 to 3,000), Cambodia (1,000 to 2,000), Vietnam (500 to 1,500), Malaysia (1,000 on the peninsula and 500 to 2,000 on the island of Borneo), Indonesia (2,500 to 4,000 in Sumatra and a small number in Kalimantan, Borneo), and Sri Lanka (2,500 to 3,000).

An additional 15,000 Asian elephants are found in captivity, mostly in Myanmar (5,000), Thailand (4,000), India (3,000), Laos, Sri Lanka, and in zoos in Europe and North America. In many Asian countries, the elephants continue to play a crucial role in logging operations; they are also used to transport tourists inside nature reserves.

The gradual, insistent decline of the Asian species is due to the loss of habitat and to the capture of elephants in large numbers to replenish captive stocks (captive breeding efforts have been grossly inadequate). The remaining elephant habitat is fragmented. Hydroelectric dam projects submerge river valleys, prime elephant habitat; canals and roads impede the movement of elephants; commercial plantations of tea, coffee, oil palm, rubber, wattle (Australian acacia), and blue gum replace natural forest; and slash-and-burn shifting cultivation creates vast areas of degraded habitat. Poaching of male elephants for ivory (female Asian elephants do not possess tusks) has resulted in unequal sex ratios in parts of India and continental Southeast Asia.

In many parts of Asia, the elephant has long been venerated as a religious symbol. This tradition of respect, combined with a growing awareness of the animal's plight, has led the governments of some Asian countries to develop specific conservation programs to save their elephant populations. India launched Project Elephant in 1992 to consolidate the elephant's habitat, reduce conflicts between elephants and humans, and insure the proper management of captive elephants. Peninsular Malaysia has an active program of capturing and translocating small, isolated herds trapped in nonviable habitats. As the first step toward preparing a conservation plan for its country, Myanmar has sought the assistance of the World Conservation Union's (IUCN) Asian Elephant Specialist Group in surveying its elephant population. All this attention is welcome and, with hard work and political will, it may help secure this great species' survival well into the twenty-first century.—*R. S.*

male in the family). She has not only her own safety to consider but also that of her entire family, and this may make her cautious.

Males, in sharp contrast to the females, typically leave their natal families when they are ten to fifteen years old to fend for themselves or join up with other bulls. Once on their own, males are much more likely to raid crop fields. On average, during my study, an adult bull entered fields forty-nine nights in the year, as compared with only eight raids by a family herd. And annually, the bulls obtained nearly 10 percent of their dietary needs from crops, while for the herds, the figure was less than 2 percent.

But elephants are individuals, not just slaves to their gender. Behavior in highly social, intelligent animals is not only genetically coded but also learned from elders and peers and thus culturally transmitted. Whether raiding crops or acting aggressively against humans, elephants behave as individuals, their actions depending on a complex interaction of their genes and their history. There was considerable variation among the bulls in my study. Some appeared infrequently in the villages; others—such as the Karapallam bull, the Akkurjorai bull (named after a patch of forest where he often sought refuge), one bull with no tusks at all, and Vinay—were regular visitors. A few were notorious: Vinay and the Akkurjorai bull, for instance, were responsible for 40 percent of all the damage caused by bulls.

Some bulls seemed to take up residence in the vicinity of villages specifically for the purpose of raiding crops. Their standard modus operandi was to enter after dark and depart before sunrise. Often they paired up or formed larger groups of three or four. By measuring the size of footprints left by the bulls on the soft soil in the fields, I was able to estimate their ages. I discovered that younger bulls were especially likely to team up, often with an older, presumably more experienced bull, before embarking on a raid. The reason seemed clear enough: when a young bull did venture into the fields on its own, farmers were able to chase it away before it could cause much damage. Even older, experienced bulls joined forces sometimes; any bull is better able to tackle ntagonistic farmers when it is part of a gang.

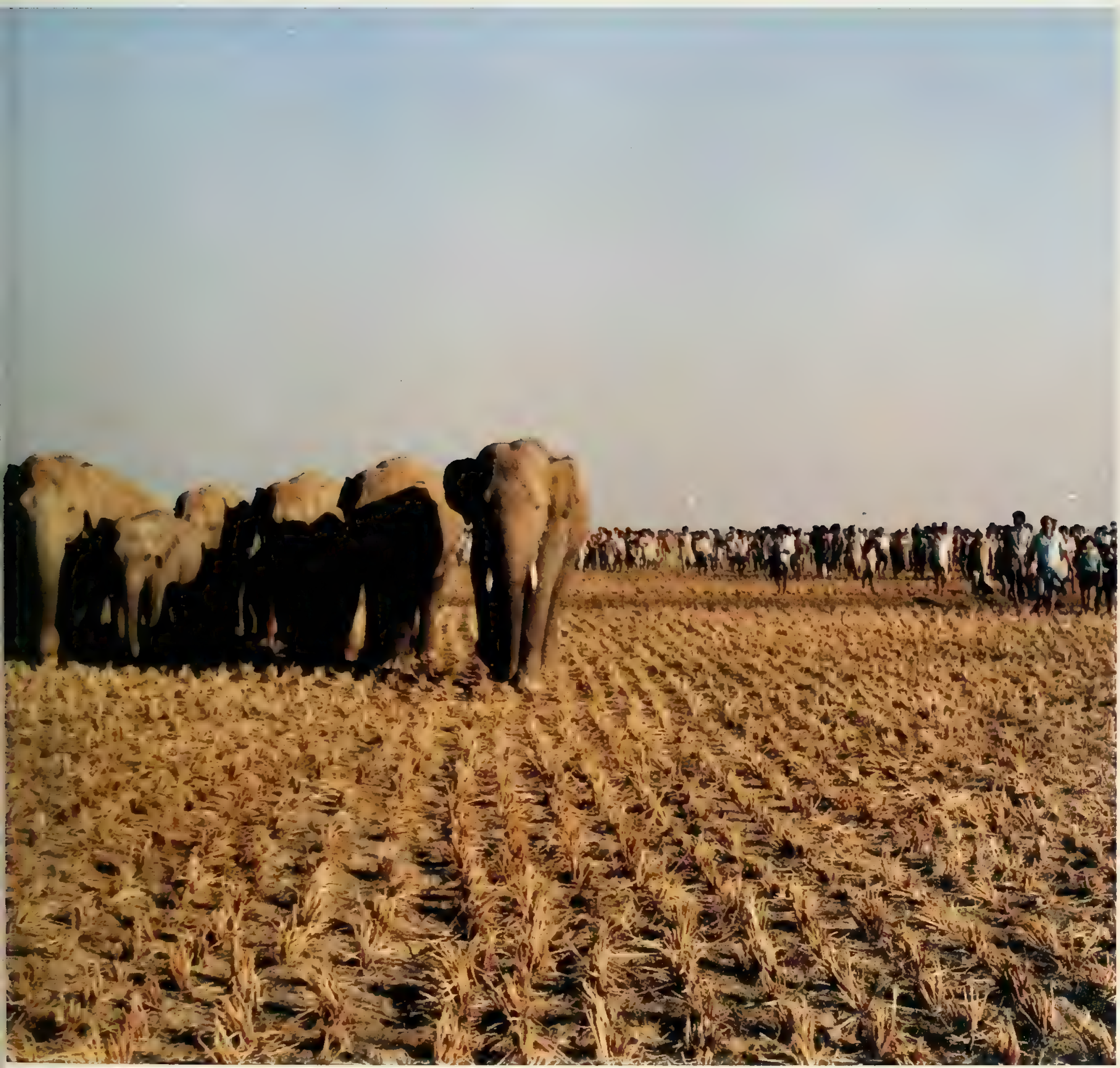
The males' more solitary lifestyle is only one xplanation for their more frequent appearance farmers' fields. For another, consider one asic difference between male and female elephants. On average, a female gives birth to about ven or eight calves over the course of her life, though a cow that survives into old age can ise up to a dozen. A much higher variation in productive success exists among males, with ominant bulls potentially siring many more offspring than subordinates, some of which may il to reproduce altogether. The stakes are thus gh for males in the elephant mating game, and ills may be willing to take greater risks to increase their chances of mating.

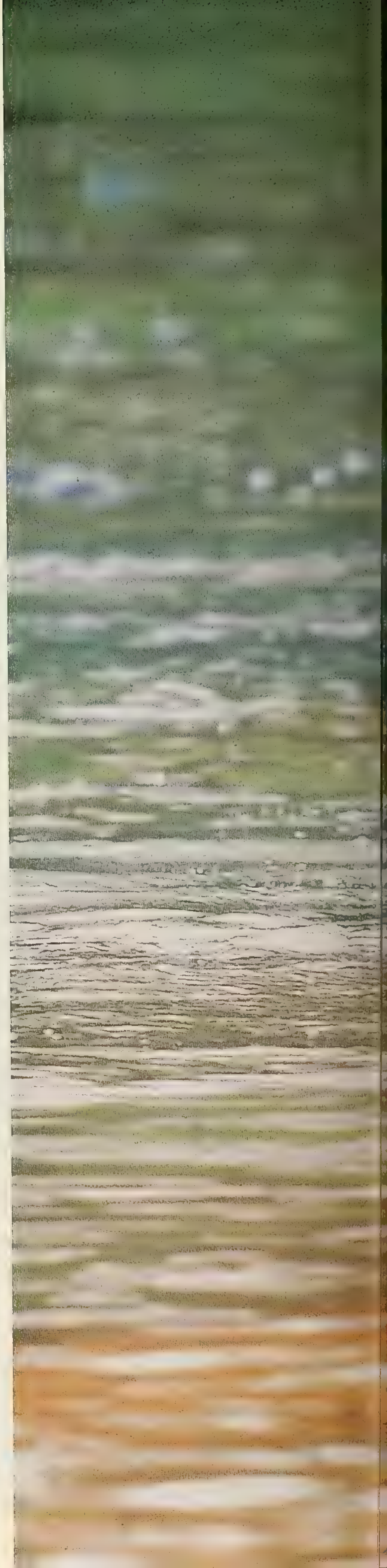
Dominance among males is determined rgely by size, which in turn is a function of ood nutrition (as well as good genes). Bulls also njoy a boost in rank and attractiveness to females when they come into musth, a rutlike physiological state that usually occurs once a year. Different bulls in the population may come into musth at different times. Musth, however, is an expensive proposition. The level of testosterone (the male sex hormone) in the blood rises dramatically, and bulls begin to secrete a fluid, also containing testosterone, from their temporal glands (situated on the sides of the head, just above and behind the eyes). A bull in musth shows little interest in feeding; his mind is fully occupied with seeking out cows in estrus, mating with them, and keeping rival bulls away.

By the time the musth flow has ceased several weeks later, the bull is in relatively poor condition. To sustain the exhausting demands of musth, a bull must be in good shape to begin with. Perhaps this explains the willingness of many bulls to venture into fields; if they can feast on enough millet and other nutritious crops, they

In 1993, a herd of elephants walked more than a hundred miles into West Bengal, raiding paddy fields as they went. Crowds of people followed their every move. The elephants were turned back only thirty miles from Calcutta.

Bhaskar Paul





Given the opportunity, elephants bathe daily and drink prodigious amounts of water. Any field that cuts off their access to water is likely to be trampled.
Manoj Shah; Tony Stone Images

may significantly increase their chances of mating successfully. Their strategy is one of high risk, high gain. Of course, taking risks is no guarantee a bull will sire more offspring; he may instead suffer a grievous wound or be killed by an angry farmer. Win or lose, however, marauding bulls are a product of evolution, their behavior shaped by natural selection.

A different explanation must be found for raids conducted by females and their herds, which, though less frequent, sometimes take place on an impressive scale. About a decade ago, elephant herds began wandering tens or hundreds of miles away from their native habitats in different regions of India. In 1983, for example, several matriarchs and their families left their original home in the Hosur Forest Division in southern India and went north into the state of Andhra, where wild elephants had not been seen for well over a century. In Andhra they ravaged crops, killing people ignorant of the dangers of getting too close to elephants.

A few years later, elephant herds from the state of Bihar began to make deep, seasonal forays eastward into West Bengal and westward into Madhya Pradesh, where elephants had been wiped out two centuries ago. In November of 1993, as one army of elephants, some fifty-strong, advanced, the excited media reported daily on their exploits in the paddy fields. By the new year, the elephants reached the Hooghly River; across the river, just thirty miles away, lay Calcutta. Only a determined effort by the authorities and the villagers acting together succeeded at last in getting the elephants to turn back toward their "home."

Efforts to save the Asian elephant require the cooperation of local people who now share its habitat.

Both at Hosur and in Bihar, denudation of habitat contributed to the elephants' excursions. Severe weather and climatic aberrations may also play a role. In 1983, a persistent El Niño caused one of this century's most severe droughts around the globe. This could have been the proverbial last straw triggering the elephants' movements. Similarly, the Bihar elephants first made their most decisive moves during 1987, another year of drought.

Over the centuries, the response of people throughout Asia to crop-raiding elephants has depended on technologies available to deter them, on cultural and religious attitudes, and on the conservation laws of the particular society. Today, in Asia, conservationists are seeking ways to reduce the conflict. Various measures are being tried, such as digging trenches along the boundary where forests meet cultivated fields and installing electrified fences, all with only limited success so far. Any solution that seeks to accommodate both elephants and people will have to be based on respect for the intelligence of these highly social creatures, which are capable of creative responses to new situations. □

Creature Conflicts

by Walter V. Reid

The Endangered Species Act, a symbol of the nation's commitment to conservation for more than twenty years, is today itself endangered. The act, scheduled for reauthorization by Congress this year, is embroiled in a controversy between critics, who claim that it places an undue burden on private landowners, and defenders, who point to its success in saving species from extinction.

Under the Endangered Species Act (ESA), the federal government maintains a list of species judged by scientists to be threatened. Listed species are protected from such direct harm as habitat destruction, and the Fish and Wildlife Service takes steps to restore their populations to healthy levels. As the government lists more species—the list now numbers 900 and some 100 are added annually—local conflicts multiply and frustration mounts.

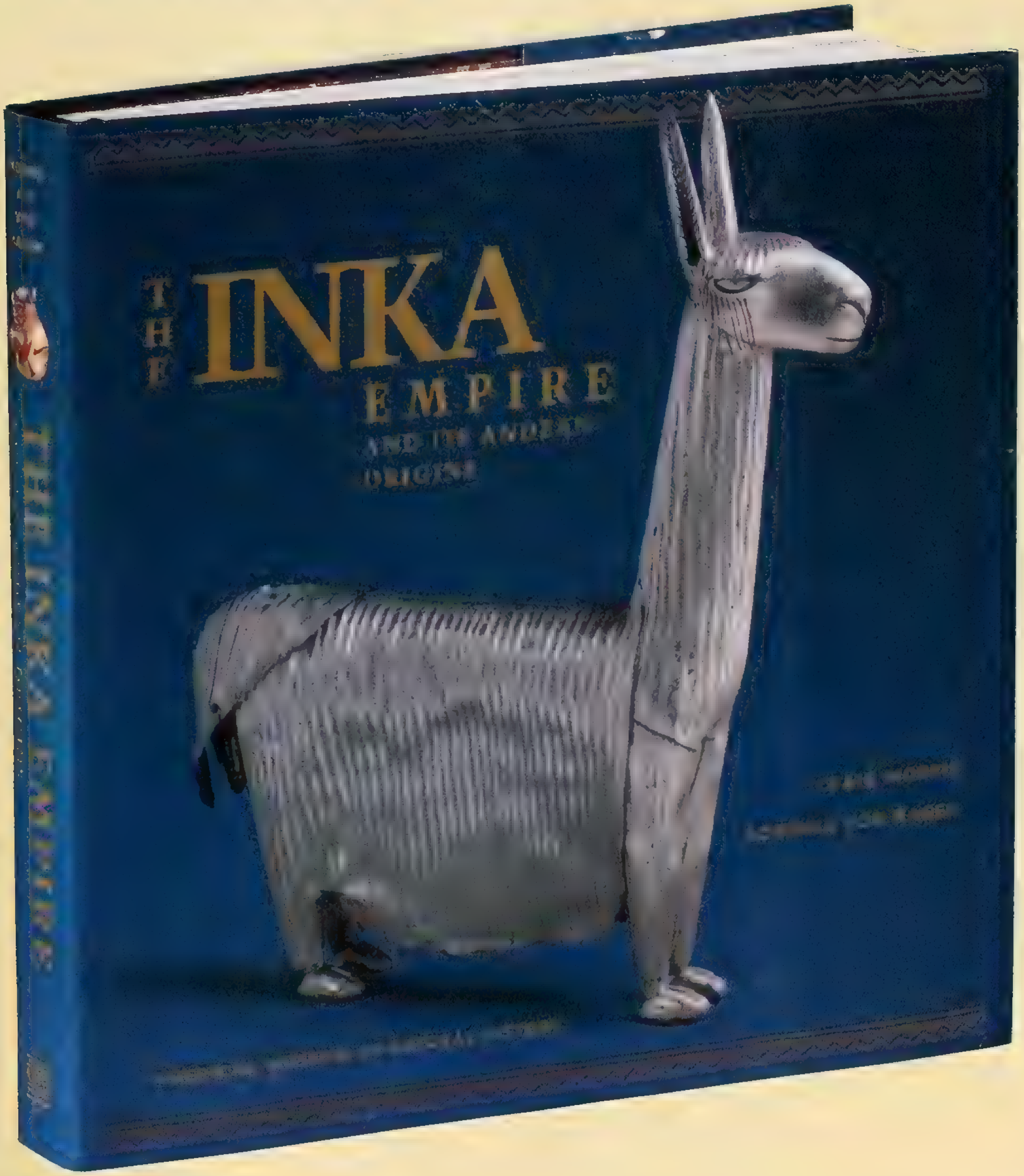
NOAH'S CHOICE: THE FUTURE OF ENDANGERED SPECIES, by Charles C. Mann and Mark L. Plummer. *Alfred A. Knopf, Inc. $24.00; 302 pp.*

The authors of *Noah's Choice,* Charles C. Mann and Mark L. Plummer, say that the ESA sets an unattainable goal of protecting all species from extinction at ar cost. They consider the policy dysfunction because some extinctions can only be pr vented at costs in excess of what peop would be willing to spend. They cite ca after case—the American burying beetl the Karner blue butterfly, the whoopi crane, the snail darter, and the black-capp vireo—in which efforts to protect the sp cies have collided with the building roads, suburbs, dams, and other kinds of d velopment. Even though endangerment a extinction are truly serious problems, Ma and Plummer assert that it is wrong to allo the protection of species to trump other s cial values, and that the economic value

Karner blue butterfly

A. M. Rider; Photo Researchers, Inc.

THE
INKA EMPIRE
AND
ITS ANDEAN ORIGINS



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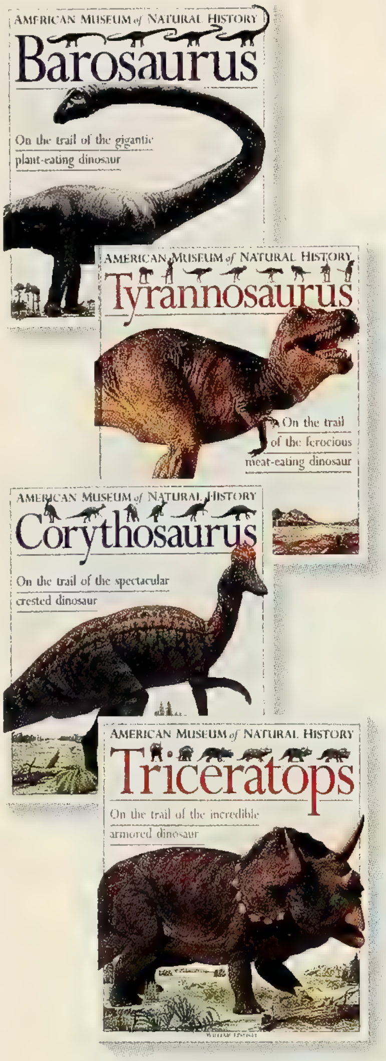

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any particular species is rarely worth th price of protection.

Even ESA's defenders acknowledg that some changes in the act are needed t address problems such as those raised i *Noah's Choice*. But is the answer the legislative surgery that Mann and Plumme propose: scaling back the scope of th ESA? A closer look at the record show that the act is achieving its goal of keepin such species as the California condor, th black-footed ferret, the California se otter, the whooping crane, and the peregrine falcon from extinction. But Man and Plummer set a higher standard fo success—recovery of healthy population not just a stay of extinction. Their argument, however, does not consider that th growing pressures on natural habita make it unrealistic to expect many specie to be fully restored in the course of a decade or two.

Conflicts with development do exist, o course, yet in the cases discussed by Man and Plummer, all the disputed projec went forward, most with only sma changes made to accommodate the ES Of some 73,000 consultations in the la 1980s between the Fish and Wildlife Se vice and various federal agencies on pr posed development activities that mig threaten endangered species, only nin teen projects were ultimately blocke canceled, or terminated.

The authors claim that the ESA "d mands that species be given the highe priority, no matter what the implications but this is simply untrue. The act requir that the government weigh social and ec nomic considerations when establishi critical habitat. The act also permits so harm to endangered species if a solid pl is developed for conserving their kind, a when white-hot conflicts arise, it specifi that a cabinet-level committee will formed to grant exemptions.

But the biggest weakness in Mann a Plummer's analysis stems from their a too-narrow focus on local land-use co flicts. Viewed through their lens, biodiv sity protection will always appear to incompatible with human needs: save species of fish but lose a dam; build a su division but lose a species of bird. The local conflicts are outcomes of more fu damental choices about the goals a paths of development. And these bedroc choices can often be the source of altern tives that simultaneously address both bi diversity and people's economic nee Consider the snail darter's David vers Goliath victory over the building of

Whooping crane
Jess R. Lee; Photo Researchers, Inc.

ellico Dam some years ago in Tennessee. ı fact, the dam was a non-starter econom- ally, and the governor of the state had alled it a waste of taxpayers' money. The ıoice was not fish versus dam, but sound conomic development and biodiversity ersus pork barrel politics.

From Mann and Plummer's perspec- ve, protecting the black-capped vireo or e Karner blue butterfly is a poor move if forecloses suburban development on the nd these species inhabit. But the real ıoice here isn't the local one between al estate developers and winged biodi- ersity, but between different patterns of ban development. Implicit in the au- ors' argument is the notion that continu- g sprawl is economically beneficial to ciety. But is it? Or does it mainly ad- nce a few entrepreneurs who buy cheap nd, profit as services are provided at tax- ıyer expense, and then leapfrog to the ext ring of development, while urban nters decay? While choosing a butterfly er a subdivision may look silly, choos- g to limit sprawl both to keep up the ıality of the environment and to protect e regional economy is anything but.

But if the radical surgery on the ESA lled for by Mann and Plummer is not the ght approach, what is? First, develop much better information on the identity and distribution of the nation's species. The holy wars over the burying beetle and the snail darter petered out once surveys revealed new populations of these species. Second, change policies, such as subsidies for farming, grazing, forestry, water use, and sprawl, that increase pressure on biodiversity at a high price to taxpayers. Third, provide better protection for the critical ecosystems that house currently endangered species. By some estimates, 85 to 90 percent of all species could be conserved by protecting the right samples of natural communities. Finally, replace the incentives that lead people to destroy the habitats of endangered species with incentives to protect those habitats.

Noah's Choice should deepen a confused public's understanding of the science and economics of trying to keep our biological heritage intact. Although Mann and Plummer's solutions come up short, this book does provide considerable insight into the problems that we confront with respect to endangered species.

Ecologist Walter V. Reid, vice president for programs at the World Resources Institute, is one of the principal authors of the book Global Biodiversity Strategy.

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ALASKA 1899: ESSAYS FROM THE HARRIMAN EXPEDITION, by George Bird Grinnell; introductions by Polly Burroughs and Victoria Wyatt. *University of Washington Press, $16.95.*

Grinnell, ethnologist, author of books about American Indians, and publisher of *Forest and Stream,* was one of the group of scientists that made up American business tycoon Edward H. Harriman's 1899 expedition to Alaska. Harriman was investigating the possibility of building a railroad under the Bering Strait and around the world. Known as the "floating university," the expedition included ornithologist and author John Burroughs, naturalist John Muir, artist Louis Agassiz Fuertes, and photographer Edward S. Curtis. Grinnell's two essays on his observations of Alaskan peoples are reprinted from the original report, published in eleven volumes from 1901 to 1905.

ALWAYS, RACHEL: THE LETTERS OF RACHEL CARSON AND DOROTHY FREEMAN, 1952–1964, edited by Martha Freeman. *Beacon Press, $35.*

In 1952, ten years before the publication of *Silent Spring,* Rachel Carson met Dorothy Freeman, her summertime neighbor in Maine, and the two began a correspondence that lasted until Carson's death in 1964. These letters provide not only a look at Carson's development as a naturalist and writer but also a record of a friendship and of the times.

From Always, Rachel: The Letters of Rachel Carson and Dorothy Freeman, 1952–1964

Stanley Freeman

West Southport,
September 28, 1953

Dear Dorothy,

The big September tides have come and gone, and every time I was down there exploring I wished you were there, too—you would have enjoyed it so . . . wind and surf made each day quite unpredictable; what should have been the lowest tide wasn't, and one day the surf was so heavy that just being down within reach of it was an adventure. I'm sending you a snapshot taken from the "edge of the edge" on September 22, to show what I mean—you know it's not supposed to look like that at low tide! . . . I am so sorry we didn't have a good tide the day you were here. When it is really low, it is nothing to see as many as thirty anemones under one ledge—big things six to eight inches long. And there are so many urchins right out on the flat rock surfaces where the tide falls down below all the Irish moss, and there is nothing but the rose-colored coralline algae encrusting the rock. And then all the Laminarias and other deep-water plants begin to show themselves, and somehow everything seems so very different.

I think the things you might have enjoyed most (as I believe I did) were these. . . . I was poking around a big rock that had thick crusts of the coralline algae that looked as though they could be broken off. I found they could be—because the pink coating was covering some very large barnacles, or rather barnacle shells, for they were empty. So I took a small mass of the stuff to the house, and spent the evening being entertained by all the creatures that were living in and on that little world that wasn't more than two inches across in any direction. Among other things, there were tiny anemones living inside the empty barnacle shells. And on the outside of the shells there was attached a whole new generation of baby barnacles. When they fed (as they did, madly, all the time I was watching) I could see that the inside of their shells, and their own little feathery appendages, were for some odd reason colored the same deep pink as the algae that were cementing their world together. The whole catalogue of creatures would be too long to list, but there were many different species and literally hundreds of individuals. (They all went home on the next low tide.)

The other especially choice thing (and I really got excited about this, because I didn't know it at all and have never seen any report of it) was the discovery that, where the pink crust of corallines over the rock has become thick and heavy enough that pieces can be chipped off, there is a whole community of creatures living in it and under it. That, again, was a whole evening's work and entertainment at the microscope, the high point of which was the discovery of an exquisitely beautiful worm (don't laugh, and don't shiver—it is the most beautiful worm in the world!) that I had never personally collected before, though of course I've seen it. The whole algal crust is riddled with the borings of things that have made a home in it, and with winding tunnels going off in all directions; sometimes one of those very tiny crustaceans that has a single, glowing eye would come up out of the darkness of such a tunnel, always reminding me of a miner with his head lamp. Well, you see I had a good time.

Sincerely,
Rachel

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THE BEAUTY OF THE BEASTLY: NEW VIEWS OF THE NATURE OF LIFE, by Natalie Angier. *Houghton Mifflin Co., $21.95.*

In a collection based on her articles for the *New York Times,* the Pulitzer Prize-winning columnist writes about current scientific research, recasting complex themes of life, sex, reproduction, healing, and death in a series of delightfully personal essays. Whether celebrating cockroach motherhood or imagining the "molecular underpinnings of life," Angier admires what she calls the beauty and the beastliness in all life forms.

BUGS IN THE SYSTEM: INSECTS AND THEIR IMPACT ON HUMAN AFFAIRS, by May R. Berenbaum. *Addison-Wesley Publishing Co., $25.*

Berenbaum, a University of Illinois entomologist, provides an entertaining guide to the physiology, behavior, social life, and diversity of insects. Spiked with entomological factoids (horseflies fly at speeds of fifteen miles per hour; silkworm caterpillars spin at a rate of about six inches a minute), the book considers the myriad ways human and insect lives interact.

THE COMPANY OF WOLVES, by Peter Steinhart. *Alfred A. Knopf Inc., $25.*

A former *Audubon* columnist and natural history writer, Steinhart traces what we know about "the tangled and shadowy relationships between fact and feeling, biology and mythology, wolf and human." He talks to researchers, visits the sites of wolf reintroductions, and weaves in the rich human history and mythology about wolves. Whether documenting wolf howling in Algonquin Provincial Park, Ontario, or wolf watching with the Nanamuiut Eskimos in Alaska's North Slope, Steinhart makes a case for the protection of this elusive animal.

DISCOVER NATURE AT SUNDOWN: THINGS TO KNOW AND THINGS TO DO, by Elizabeth P. Lawlor. *Stackpole Books, $14.95.*

After the sun goes down, opossums gather nest material with their tails, nighthawks seine the air with open beaks, and moonflower, evening primrose, and meadowsweet unfurl their white, cream, and pale yellow or pink blossoms to attract night pollinators. Here is a guide to what you can see and hear in the dark, as well as what to bring along in order to explore the nature of the night.

THE ENGINEER IN THE GARDEN, by Colin Tudge. *Hill and Wang, $22.*

British science journalist Tudge writes a readable primer on the science of genetics, from cloning to engineering antibodies. He is an enthusiastic proponent of technology's potential to solve present problems or avert future disasters, whether by restoring extinct animals from samples of stored DNA, creating life forms from molecules other than DNA, or providing "agriculture that can feed 10 million people . . . without destroying the rest of the environment."

THE FOSSIL TRAIL: HOW WE KNOW WHAT WE THINK WE KNOW ABOUT HUMAN EVOLUTION, by Ian Tattersall. *Oxford University Press, $25.*

Tattersall, head of the anthropology department at the American Museum of Natural History, takes the reader through more than two centuries of discoveries in human evolution, and tells how these finds have been interpreted—and misinterpreted. This lively, opinionated, personal account offers rare histories, hoaxes, and scientific fads; a readable, up-to-date account of current theory; and a healthy skepticism based on the author's own quest for our origins.

HEART OF THE LAND: ESSAYS ON LAST GREAT PLACES, edited by Joseph Barbato and Lisa Weinerman of The Nature Conservancy; foreword by Barry Lopez. *Pantheon Books, $24.*

The particular intimacies of place are presented here in a collection of essays by thirty writers, including Louise Erdrich, Gary Paul Nabhan, Peter Matthiessen, William Least Heat-Moon, and Ann Zwinger.

MANY RIVERS TO CROSS: OF GOOD RUNNING WATER, NATIVE TROUT, AND THE REMAINS OF WILDERNESS, by M. R. Montgomery. *Simon and Schuster, $22.*

Montgomery, a journalist with the *Boston Globe,* likes to fly fish, which takes him back where he grew up, the Big Dry of eastern Montana, looking for cool, clea streams where trout still live. From there he moves around the West, exploring waterways and giving a thoughtful, evocative picture of what he finds in them—both fish and foul.

MAPPING FATE: A MEMOIR OF FAMILY, RISK, AND GENETIC RESEARCH, by Alic Wexler. *Times Books, $23.*

What begins as a project to documen the biomedical research involved in finding the gene for Huntington's disease becomes a dramatic memoir as Wexler, wh herself has a 50-50 chance of inheritin HD, tracks the advances in understandin this devastating disease.

NOTES FROM THE SHORE, by Jennifer Ackerman. *Viking Penguin, $21.95.*

"I live in a small town by the sea. It sit just inside Cape Helopen at the bottom li of Delaware Bay." From this corner of th Atlantic coast, Ackerman explores an observes the natural life of the marshes mud flats, and sand dunes along th ocean's fringes.

Arnold Arboretum, Boston, circa 1900; from Olmsted's America: An "Unpractical" Man and his Vision of Civilization, *by Lee Hall.*

Olmsted Collections; National Park Service

Eskimo winter hut, by Edward S. Curtis; from Alaska 1899: Essays from the Harriman Expedition, *by George Bird Grinnell*
University of Washington Press

OLMSTED'S AMERICA: AN "UNPRACTICAL" MAN AND HIS VISION OF CIVILIZATION, by Lee Hall. *Little, Brown and Company Inc., $40.*

Olmsted, who came of age before the Civil War, called himself "strangely uneducated,—miseducated . . . chiefly taught how not to study." Yet Olmsted was the father of landscape architecture in America. Author Hall points out that Olmsted's legacy, from Central Park in New York to his plan for Leland Stanford's university in California, was "of the power of design to preserve natural beauty and to create oases of nature within the cityscape."

OUR NATURAL HISTORY: THE LESSONS OF LEWIS AND CLARK, by Daniel B. Botkin. *The Putnam Berkeley Group Inc., $24.95.*

After reading the Lewis and Clark journals, Botkin, who is president of Santa Barbara's Center for the Study of the Environment and director of the program for global change at George Mason University, was struck by how much natural history was included in their epic journey across the continent and back between 1804 and 1806. In his book, Botkin examines the journals and compares the present nature of the West with that of the past. "If we begin to understand the true nature of our natural heritage," writes Botkin, "we will learn what we have and have not done to it, and we can become the stewards of our environment."

THE PRAIRIE KEEPERS: SECRETS OF THE GRASSLANDS, by Marcy Houle. *Addison-Wesley Publishing Co. Inc., $20.*

An investigation of the thriving hawk population in a 200-square-mile plot of Oregon prairie leads biologist Houle to an understanding of the ecosystem's human, animal, and plant life.

THE SAND DOLLAR AND THE SLIDE RULE: DRAWING BLUEPRINTS FROM NATURE, by Delta Willis. *Addison-Wesley Publishing Co. Inc., $23.*

Science journalist Willis writes about the relationship between human designs and nature's forms: the fractals of trees, the engineering of sea urchin domes, the structures of butterfly wings and nautilus shells, the chaos theory that describes how water splashes. Willis resurrects the ideas of Scottish biologist D'Arcy Thompson, demonstrating how his pioneering studies of natural form have influenced a new generation of biologists, architects, and physicists.

SOMETHING HIDDEN BEHIND THE RANGES: A HIMALAYAN QUEST, by Daniel Taylor-Ide. *Mercury House Inc., $14.95.*

Taylor-Ide grew up in India and has spent much of his career as a field biologist, conservationist, and public health and education administrator in Nepal. His fascination with reports of the yeti took him to Nepal's remote Barun Valley, where he unraveled the mystery of the yeti and contributed to the preservation of the Valley as a national park.

SPELL OF THE TIGER: THE MAN-EATERS OF SUNDARBANS, by Sy Montgomery. *Houghton Mifflin Co., $22.95.*

The vast mangrove swamps of India and Bangladesh are known as Sundarbans. Montgomery visits the area to try to observe the tigers firsthand. Though she barely glimpses one, she discovers much about the lore surrounding these "man-eaters" and the power of this wild creature over the local population.

STRANGE GENIUS: THE LIFE OF FERDINAND VANDEVEER HAYDEN, by Mike Foster. *Roberts Rinehart Publishers, $29.95.*

Before and after the Civil War, geologist-naturalist Hayden took part in systematic efforts to explore and map the West. His survey of the Yellowstone region, documented by photographer William Henry Jackson, brought the area to public attention and paved the way for the creation of Yellowstone Park in 1872.

THE THIRD CULTURE: BEYOND THE SCIENTIFIC REVOLUTION, by John Brockman. *Simon and Schuster, $25.*

In this collection, twenty-three scientists from all disciplines express their ideas about important questions—both literary and scientific—facing humankind. Brockman, a literary agent for many of these scientists, believes their contributions bridge the gap between literary and scientific thinking, the subject of C. P. Snow's book *The Two Cultures.*

WATER, ICE AND STONE: SCIENCE AND MEMORY ON THE ANTARCTIC LAKES, by Bill Green. *Harmony Books, $23.*

Green, a limnologist at Ohio's Miami University, has spent more than seven field seasons in Antarctica. While dealing with the dangers of the harsh, bleak landscape, he managed to understand the ecology of Antarctica's little-known freshwater lakes and their microscopic life forms.

WHERE BIGFOOT WALKS: CROSSING THE DARK DIVIDE, by Robert Michael Pyle. *Houghton Mifflin Co., $22.95.*

In a month-long October trip along the Dark Divide in Washington's Southern Cascades, ecologist Pyle "prospects for stories" about Bigfoot, or Sasquatch. Encounters with ghost moths, butterflies, a fossil Bigfoot track, and motorcycle furrows lead him to conclude that "if we manage to hang on to a sizable hunk of Bigfoot habitat, we will at least have a fragment of the greatest green treasure the temperate world has ever known."

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Continued from page 9

that wiped out the dinosaurs—the mass dying at the end of the Triassic period. More basically, evolution's unpredictability is fractal and present at all scales. We can trace, in retrospect, what happened during those 150 million years, and we may be able to explain the results in evolutionary terms. But we could not have predicted the outcome at the outset, any more than we could have looked out from Concord Bridge on April 19, 1775, and known that Eisenhower's forces would invade Normandy 169 years later. Evolution has no pathway that goes forward in sameness if not disrupted by externalities.

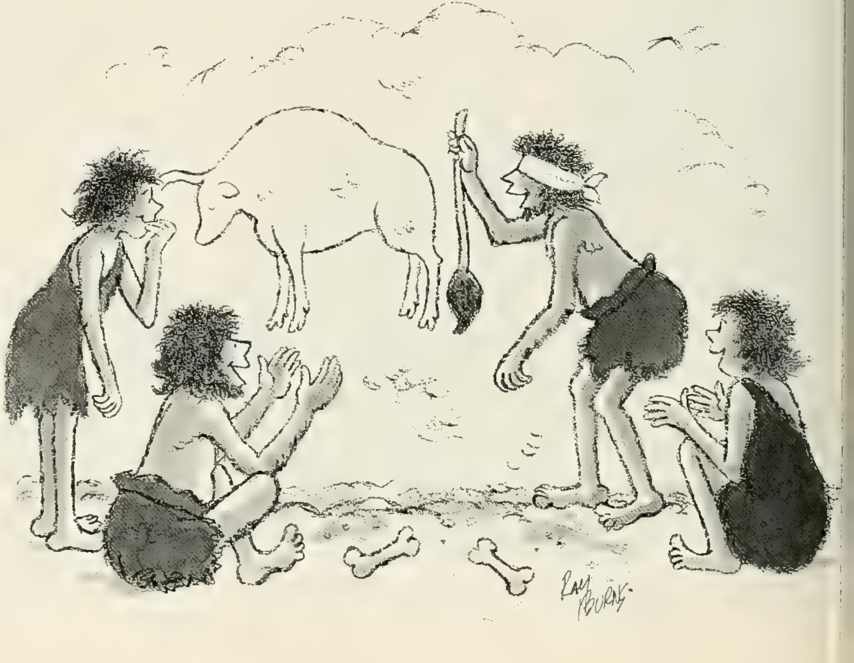
3. *Continuous flux.* Since my first two examples involved letters mistakenly critical of articles in the Science Times section, let me strive for journalistic balance by exposing a spin-doctored fallacy in a Science Times article of March 14, 1995.

Judging from the dozen or so requests that I later received for interviews and comments based upon this article, the piece obviously inspired a great deal of interest and struck most readers as strange, fascinating, and unexpected. I declined all the interviews because, as I explained, the article was correct and had expressed something important about evolution. But the phenomenon described was entirely expected and orthodox, not at all surprising—that is, unless one has adopted a spin-doctored view of evolution.

The article, by William K. Stevens, bore the title: "Evolution of Humans May at Last Be Faltering" and opened with the following lead sentence: "Natural evolutionary forces are losing much of thei power to shape the human species, scientists say, and the realization is raising tantalizing questions about where humanit will go from here. Is human evolution ending, ushering in a long maturity in whic *Homo sapiens* persists pretty much unchanged?" (Oh how I love that universa and anonymous appeal to authority—"scientists say"!) The article then gave an accurate account of the fact that huma anatomy has not altered substantially fo the past 100,000 years or so. The Cro Magnon people who painted the grea caves of Europe some twenty to thirt thousand years ago were indistinguishabl from us.

Interesting fallacies are often subtl often based upon hidden assumptions unstated and probably unconsciously hel As a professional evolutionist, I find nothing whatever surprising about human stability over 100,000 years. This interva while not quite so short as an evolutionar eyeblink, represents a pretty damned sma unit of geological time. Most species ar stable during most of their geological duration. Large, successful, well-adapte mobile, geographically widespread species are particularly prone to stability— because evolutionary events are concentrated in episodes of branching speciatio within small, isolated populations. *Hom*
sapiens possesses all these attributes f stability, so why should we be surprised the reported results? And why shoul Stevens's article have elicited such strong response of virtual astonishment?

I can only conclude that the spin-doc



tored view of life's history conceives of evolution within species as a continuous flux of improvement and adaptation. We are particularly prone to expect such a result for our own species. After all, we evolved from small-brained ancestors, and we have achieved our exalted status by cranial enlargement. Shouldn't this process, as intrinsic, be continued during our period of maximal spread and success? Therefore, if we have truly stabilized, isn't something funny going on, and mustn't that something be an imposition of our cultural discoveries upon our biological estate? No, no, a thousand times, no. Our stability is orthodox—at least within a fully revolutionary Darwinism with smashed pedestals.

Correct the three errors, and we may grasp evolution as a process causally driven by struggle among individuals for reproductive success, and not by any principle working bountifully for the good of species or any other "higher" entity in nature. We may then view life's history as an unpredictable set of largely fortuitous, and eminently interruptible, excursions down highly contingent pathways. And we will understand successful species as islands of temporary stability, not as striving packages in a flux of constant improvement.

Just as the first error appeared in the *Times* on the fiftieth anniversary of D-Day, the last occurred on March 14, 1995, the date of the *Times*'s 50,000th issue. The editor marked the occasion with the restrained fanfare typical of a newspaper that still refuses to publish the funnies. Arthur Ochs Sulzberger, chairman of the New York Times Company, sent a memorandum to his staff: "The best way we can celebrate is by insuring that our 50,001st edition is the best newspaper we can possibly produce." Rather like evolution devoid of the spin doctoring that has so sadly prevented the completion of Freud's revolution! Not the saccharine motto of faith cures for the past hundred years: "Every day, in every way, I'm getting better and better." But the toughness and true heroism of a player up against a house with infinite resources: hang in there, as best you can, for as long as you can. No ignobility, but only enlightenment, attends our reduction to appropriate size. For when we smash pedestals, we grant a ray of freedom to our very own defining evolutionary peculiarity, the human mind. I don't know if the truth can make us free, but I do believe that our unique mentality thrives on this form of soul food, whatever the pain of lost illusions.

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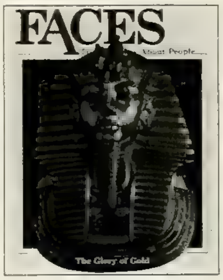

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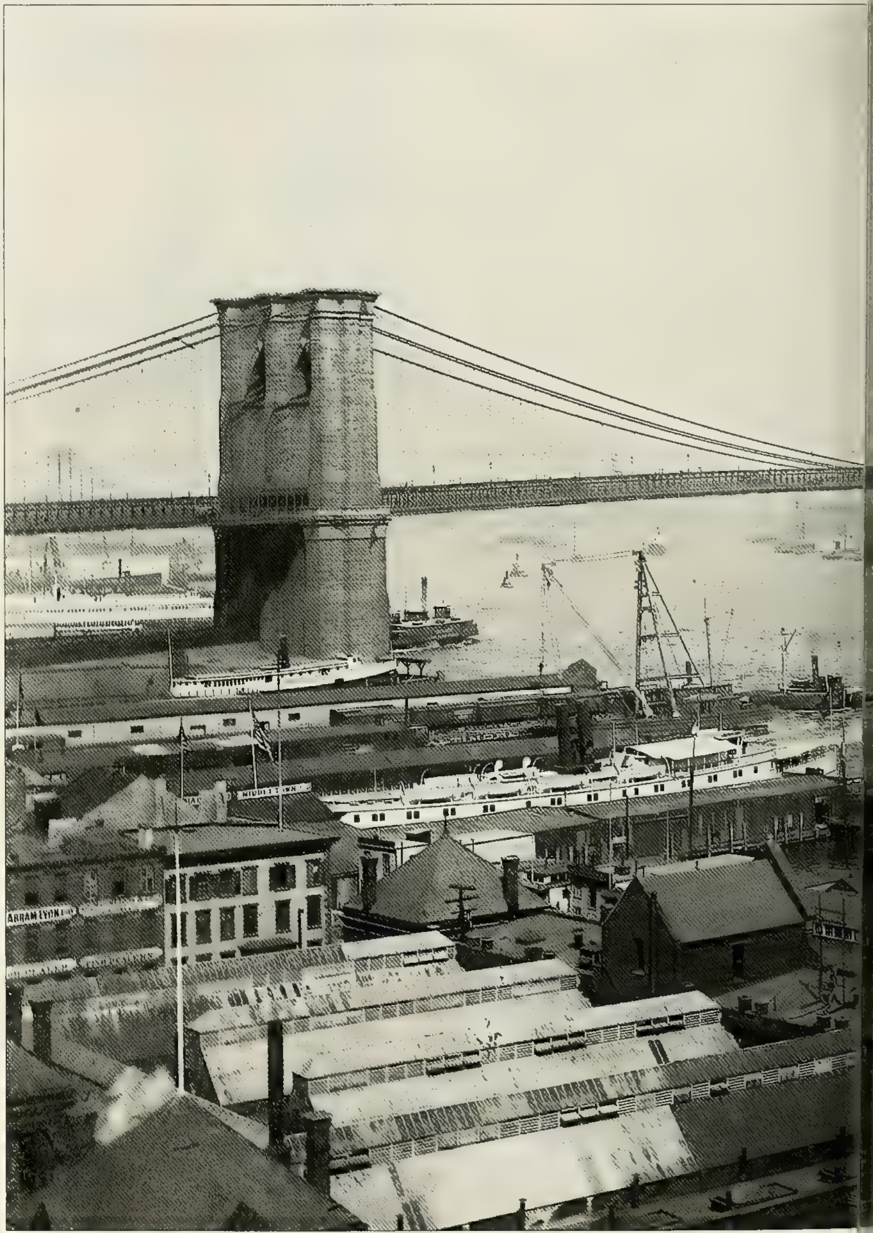

View looking north from Fulton Market and Fulton Fish Market to Brooklyn Bridge, circa 1905

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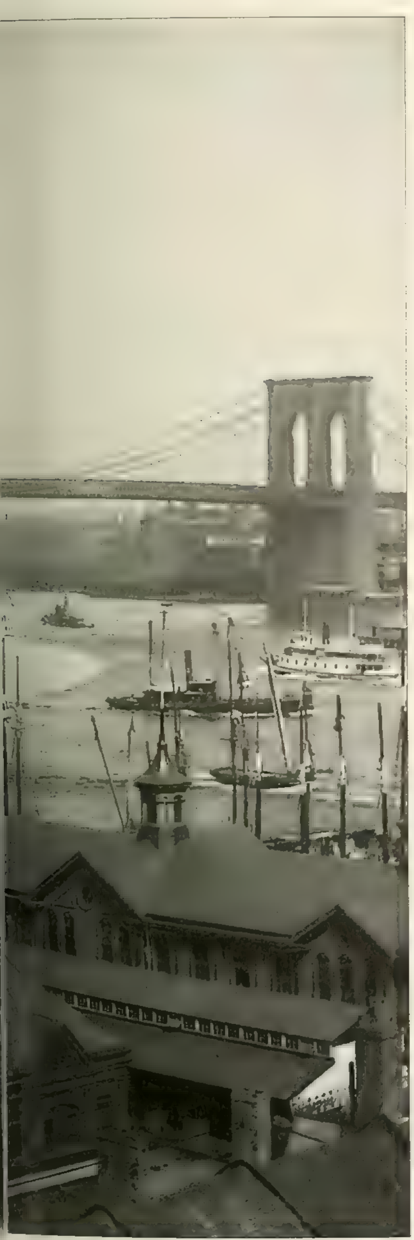

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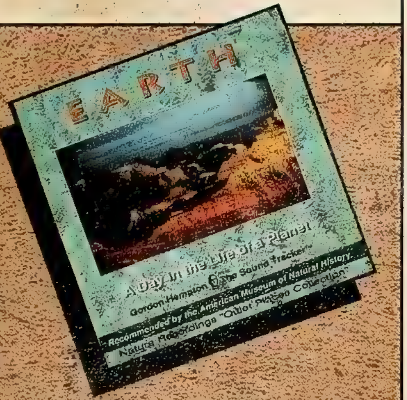
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NATURE'S INFINITE BOOK

Continued from page 12

ready differing wild aurochs populations?

The earliest, widely accepted archeological evidence for domesticated cattle places them in Anatolia (modern Turkey) by approximately 5800 B.C. By 2500 B.C., both humped and humpless cattle inhabited the Indus Valley, as evidenced by finds from archeological sites. Even before that, humped cattle were depicted in Mesopotamian art, raising the possibility that they reached India from the west (rather than vice versa). A further complication is that some archeologists believe they have found bones of domesticated cattle in ancient North African sites that are possibly older than the oldest Eurasian sites providing similar evidence. This suggests independent domestication of cattle by Africans. Other archeologists, perhaps the majority, consider those bones to be those of wild aurochs.

Recent discoveries that help resolve these questions come from the field of molecular genetics. Recall that our genetic material consists of long molecular strands termed DNA, made up of small units known as nucleotide base pairs. Most DNA of higher animals is confined to cell nuclei, but some occurs in intracellular particles called mitochondria. Mitochondrial DNA evolves more rapidly and varies much more between individuals, populations, and species than does nuclear DNA. As a result, mitochondrial DNA is more useful for tracing relationships of closely related populations, since nuclear DNA may exhibit too little variation to analyze profitably. That's why the controversial "mitochondrial Eve hypothesis" of cent human origins was based on stuc of human mitochondrial DNA.

To exploit DNA's potential value tracing relationships, scientists determ the sequence of nucleotide base pairs corresponding DNA chains of individu drawn from different populations or s cies. This permits them to put a number the genetic difference between the popu tions. If researchers see one cow wit hump and another without one, that obs vation still leaves them wonder whether the cows differ in 0.1 percen percent, or 10 percent of their genes. DNA analyses permit such statements "Cow *A* and cow *B* differ in 35 out of base pairs analyzed." Extending the ana ses to more cows, we can deduce relati ships. If cow *C* differs in 38 base p from cow *B* but in only 2 base pairs fr cow *A*, we conclude that cows *A* and *C* much more closely related to each ot than either is to cow *B*. In additi anatomical features such as humps may influenced by diet and environment, DNA base pair sequences are not. Fina superficially similar anatomical structu may arise repeatedly and independe through convergent evolution (as did wings of birds and bats), but two unrela species are extremely unlikely to evo identical sequences of 898 DNA b pairs independently of each other.

Those are the principles behind a st of cattle relationships carried out Ronan Loftus and four colleagues at Tr ity College, Dublin. Of the 800 breeds cattle, the Dublin team selected thirteen order to sample the spectrum of mod breeds. Six were humpless Europ

Humpless European cattle, Zweisimmen Valley, Switzerland
Wolfgang Kaehler

reeds, including such familiar ones as ereford, Jersey, and Friesian. Three were umped zebu breeds from India. The other our were from Africa: two humped reeds from East Africa and one humped nd one humpless breed from West Africa. or two individuals of each of the thirteen reeds, the Dubliners determined the base air sequence of the most variable (and ence the most informative) part of mitohondrial DNA, its so-called D loop. For ve more individuals of each breed they equenced the most variable part of the D oop itself. They also compared D loop NA in about ten other individuals per reed by a quick-and-dirty method called FLP (restriction fragment length polyorphism). Finally, they studied bison, a ild, hoofed mammal species related to attle but in anyone's view less closely reated to any cattle breed than either European, Indian, or African cattle are related one another.

The Dubliners' results were striking. irst, they found that, *within* each continent, *all* the studied breeds were very osely related to one another. Within the frican, European, and Indian groups, cate breeds differed, on the average, in only .4 percent of their analyzed base pairs. hat is scarcely greater than the average ifference among individuals of the same reed. But that result isn't so surprising. veryone agrees that European domestiated breeds were derived from a common ncestor within the last 8,000 years, and ave therefore had, at most, only that odest length of time to diverge from one nother; and that Indian cattle breeds have milarly had only that time to diverge om one another.

The differences among breeds within a ontinent were slight, but the gap between ndian and European cattle proved to be normous. Five percent of the analyzed ase pairs differed, fully 12 times the inacontinental difference. What can that 5 ercent figure tell us about how long the ontinental breeds have been separated?

Fortunately, we have a guidepost. The ossil record indicates that the ancestors of attle and of bison diverged about one milon years ago, and possibly earlier. Yet the NA difference between bison and any attle breed is only about 6.7 percent, little ore than the 5 percent difference beveen European and Indian breeds. Asuming a constant rate of DNA change, uropean and Indian cattle must have dierged from each other only slightly less han a million years ago.

Since cattle domestication began much

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March 11-29, 1996

Scattered across a thousand miles of ocean and isolated from the continents, the remote islands of the Indian Ocean are treasure-troves of rare and unique species. This winter, a team of lecturers from the American Museum of Natural History will host an Indian Ocean voyage to these exotic islands. Along the way, we will see an impressive array of plant and animal life, some that exist nowhere else in the world. Among the highlights are Aldabra's thousands of giant land tortoises, enchanting lemurs on Madagascar, a wonderland of thousands of 100-foot-tall coco-de-mer palms on Praslin and sightings of some of the world's rarest birds, including the last black parrots, the Aldabra drongo, the beautiful black paradise flycatcher and the only remaining flightless bird in the Indian Ocean—the white-throated rail. Program rates start at $6,480.

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more recently than that, those big differences separating Indian from European cattle must have arisen mainly before domestication rather than after it. That is, Indian and European cattle must have been independently domesticated from geographically separate populations (different subspecies) of wild aurochs, which had already had hundreds of thousands of years to diverge. One aurochs population must have been domesticated somewhere in the eastern part of Eurasia, possibly between eastern Iran and India, and another somewhere in the western part of Eurasia, very likely between Anatolia and Mesopotamia. Most of the differences that can be measured today between Indian and European cattle breeds must already have distinguished the ancestral western and eastern species of aurochs. It was not the case, therefore, that European domestic cattle were derived from Indian domestic cattle (or vice versa); the differences between them are much too great to have arisen since a single domestication in the last 8,000 years.

Thus, Ronan Loftus and his Trinity College colleagues seem to have resolved—at least, to my satisfaction—the debate over the respective origins of European and Indian domestic cattle. Those scholars who believed in independent origins were right; those who believed in common origins were wrong. But the Dublin team's findings about the origins of African cattle are likely to come as a surprise to both schools of thought.

First, the sole humpless breed of cattle they studied, the West African N'Dama, proved to be no more different from the three humped breeds of African cattle studied than the three humped breeds were from one another. In both cases, the differences make up a mere 0.4 percent of the base pairs sequenced. Second and even more surprising, all four African breeds, including the three that are humped, are much closer to the humpless European breeds than to the humped Indian breeds. The former difference is only 0.4 percent; the latter a whopping 5 percent. As far as mitochondrial DNA is concerned, a cow's hump is a red herring. Thus, there is no evidence for independent domestication of cattle in Africa. But the source of African cattle was a surprise.

Nevertheless, we can't just stop here, shrug off humps as a red herring, and go back to work satisfied with our new understanding of cattle origins. A hump is still a hump and has to be explained somehow. We still need to understand why Africa's humpless N'Dama cattle are so similar African humped cattle. We still need to ac count for the evidence from physiolog cytogenetics, and proteins that seemed point to an Indian origin of Africa humped cattle. And we can't dismis archeological evidence that Indian catt actually were introduced into Africa, b ginning with the Arab invasions of th seventh century and later. What happene to the genes of those introduced India cattle, and how did African cattle acqui their hump?

They may have gotten it from India cattle, after all. I haven't yet mentioned catch in the studies of mitochondrial DN by Loftus and his colleagues. Mitocho drial DNA is inherited only from th mother, most nuclear DNA is inherited a copy of both the mother's and the f ther's DNA, and the so-called Y chrom some of our nuclear DNA is inherited on from the father. If male Indian cattle ha been introduced to Africa, one wou never have been able to deduce it fro studies of mitochondrial DNA. No matt how Indian cattle in ancient times we brought to Africa—whether by land ov the Suez isthmus, by water across the R Sea, or across the Indian Ocean fro India—the task couldn't have been eas and there couldn't have been many Indi cattle introduced. The most efficient w for ancient cattle breeders to bring des able humped cattle to Africa would ha been to transport small numbers of mal to inseminate the many humpless femal already present.

Thus, African cattle may have had crossbred origin, resulting from an earli introduction of European and Near Ea ern humpless cattle of both sexes, fo lowed by a later introduction of most male Indian humped cattle. If this scenar is correct, then modern African bree would owe their drought and heat tol ance, and (insofar as they have them) th humps, to their Indian great-great- . . great-grandfathers. But they would st owe their mitochondrial DNA to th great-great- . . . great-grandmothers.

This tale of crossbred cows has ma broad implications. I shall mention o three: for other domestic animals, f human population histories, and for t battleground of diffusionists again inventionists.

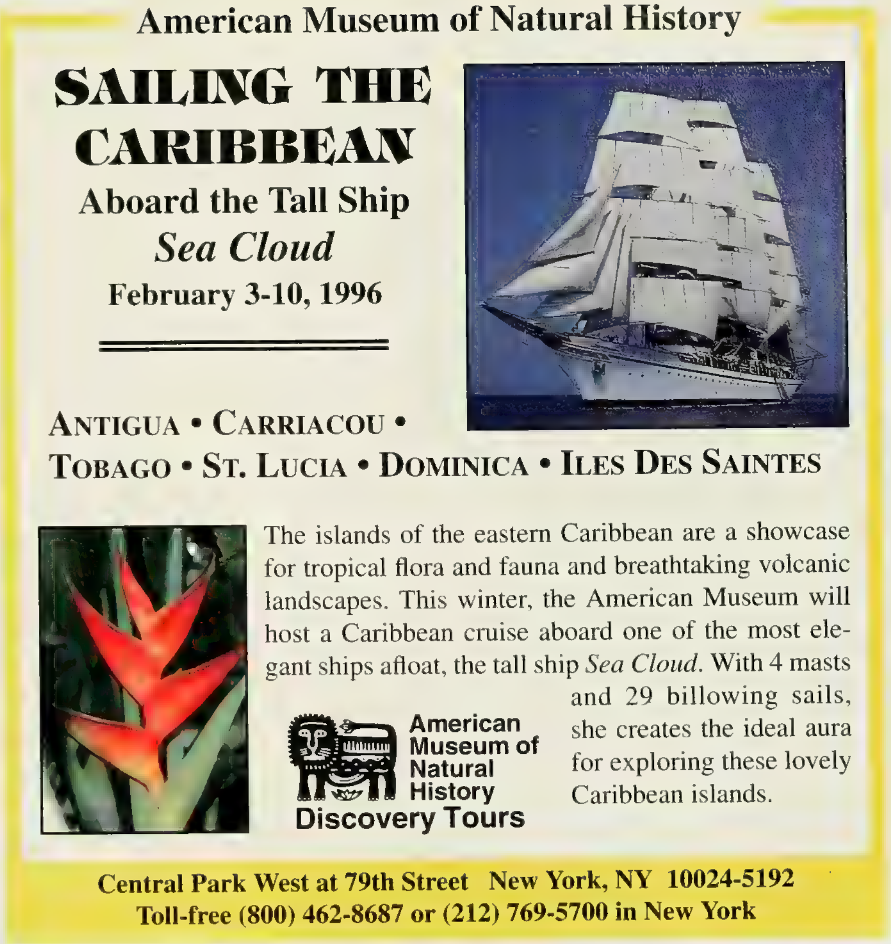
First, essentially the same debate tha have described for cattle origins arises the origins of other domesticated anim and plants. Did American Indians a Eurasians get their dogs by independen omesticating wolves? Domestic dogs are pparently at least as ancient in the Amer- cas as in the Old World, so independent omestication seems possible—unless the rst ancestral Indians arriving from Asia cross the Bering Strait had brought urasian dogs with them. Did the Chinese nd Mesopotamians domesticate pigs in- ependently? I wouldn't be surprised if ome molecular geneticists are already at ork on these questions. If they aren't, ey ought to be.

Second, one can think of modern "hy- rid" human populations whose paternal nd maternal genes may have come from redominantly different geographic ources, just as did those of African cattle. or example, in the early nineteenth cen- ury the European settlers of Tasmania early exterminated that island's Aborigi- al population (*see* "In Black and White," *atural History,* October 1988). Appar- ntly, the sole survivors were Tasmanian omen enslaved or otherwise acquired by hite sealers. Today their descendants, umbering in the thousands, are strug- ling for their rights and their identity ithin white-dominated Tasmanian soci- ety. If their genes were investigated, ould the maternal genes of their mito- hondrial DNA prove to be mainly Abo- iginal Tasmanian, their Y chromosomes mainly European, and their other nuclear enes a mixture? It seems possible that ifferent populations may also have made ifferent relative contributions to paternal nd maternal genes of African Americans.

Finally, what general conclusions can we now draw about the battle between the diffusionists and the inventionists? I say, one, because there *is* no general conclu- ion. Indian and European cattle were "in- vented" (read "domesticated") indepen- ently. African cattle seem instead to have rrived by diffusion, both from India and rom western Eurasia. Pyramids were in- vented independently in Mexico and in Egypt. So were wheels and writing. But wheels seem to have diffused west and ast in the Old World from their site of in- vention near the Black Sea. So did domes- icated barley and horses (*see* "Spacious Skies and Tilted Axes," *Natural History,* May 1994).

Thus, some cows are like pyramids and other cows are like Old World wheels. Every battle of the diffusionists and the inventionists has a separate victor.

Jared Diamond is a physiologist and evolutionary biologist at UCLA Medical School.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Aboard the Tall Ship
Sea Cloud
February 3-10, 1996

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The islands of the eastern Caribbean are a showcase for tropical flora and fauna and breathtaking volcanic landscapes. This winter, the American Museum will host a Caribbean cruise aboard one of the most elegant ships afloat, the tall ship *Sea Cloud*. With 4 masts and 29 billowing sails, she creates the ideal aura for exploring these lovely Caribbean islands.

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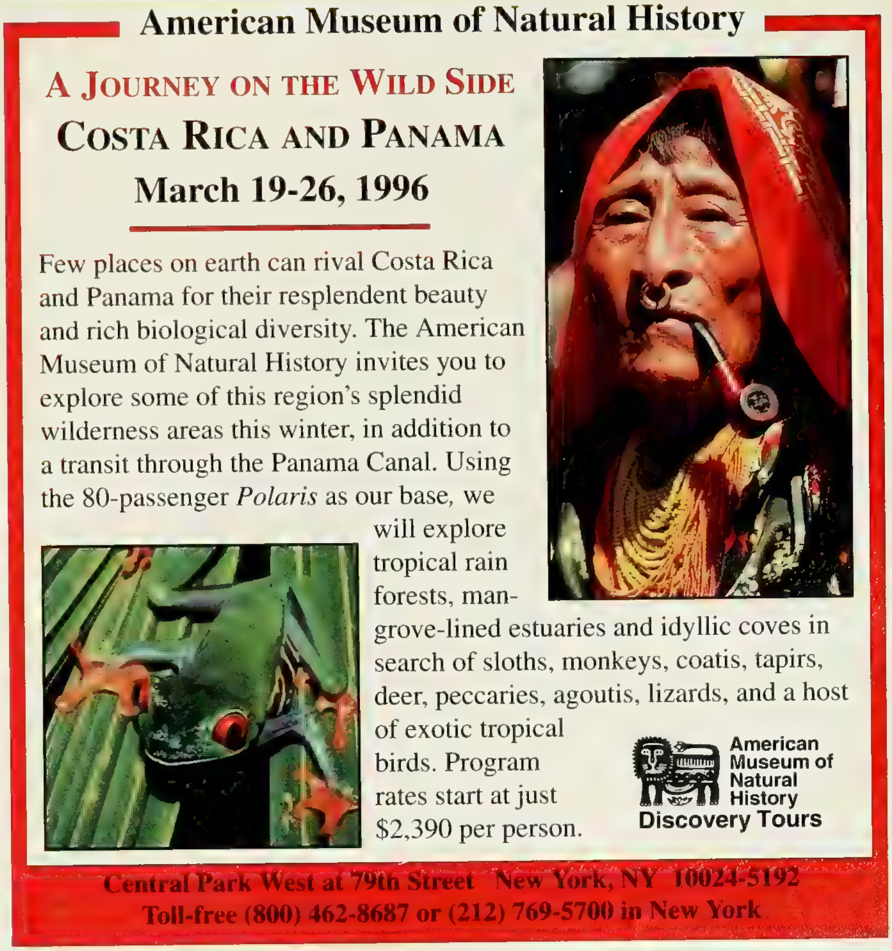
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March 19-26, 1996

Few places on earth can rival Costa Rica and Panama for their resplendent beauty and rich biological diversity. The American Museum of Natural History invites you to explore some of this region's splendid wilderness areas this winter, in addition to a transit through the Panama Canal. Using the 80-passenger *Polaris* as our base, we will explore tropical rain forests, mangrove-lined estuaries and idyllic coves in search of sloths, monkeys, coatis, tapirs, deer, peccaries, agoutis, lizards, and a host of exotic tropical birds. Program rates start at just $2,390 per person.

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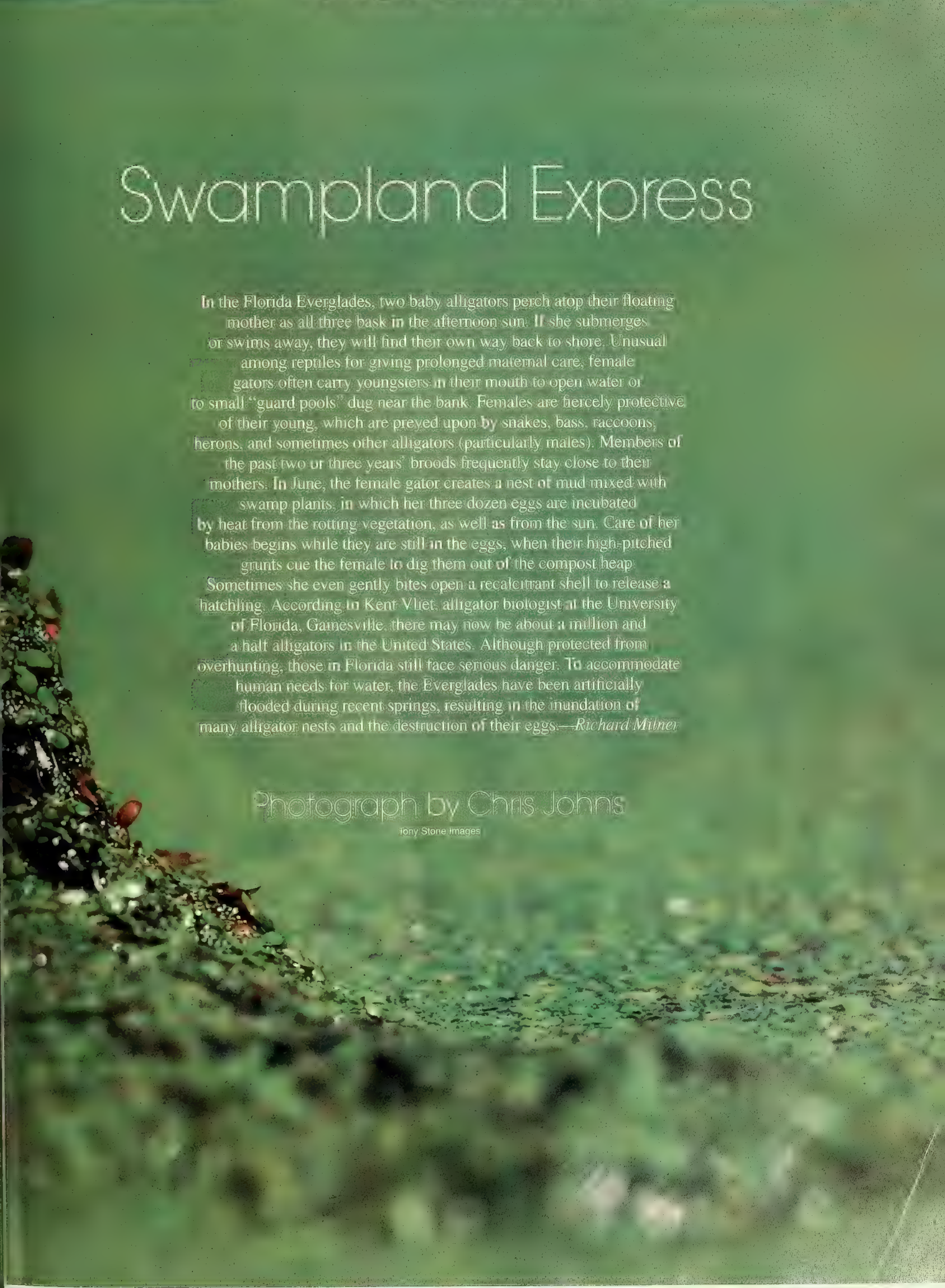
Swampland Express

In the Florida Everglades, two baby alligators perch atop their floating mother as all three bask in the afternoon sun. If she submerges or swims away, they will find their own way back to shore. Unusual among reptiles for giving prolonged maternal care, female gators often carry youngsters in their mouth to open water or to small "guard pools" dug near the bank. Females are fiercely protective of their young, which are preyed upon by snakes, bass, raccoons, herons, and sometimes other alligators (particularly males). Members of the past two or three years' broods frequently stay close to their mothers. In June, the female gator creates a nest of mud mixed with swamp plants, in which her three dozen eggs are incubated by heat from the rotting vegetation, as well as from the sun. Care of her babies begins while they are still in the eggs, when their high-pitched grunts cue the female to dig them out of the compost heap. Sometimes she even gently bites open a recalcitrant shell to release a hatchling. According to Kent Vliet, alligator biologist at the University of Florida, Gainesville, there may now be about a million and a half alligators in the United States. Although protected from overhunting, those in Florida still face serious danger. To accommodate human needs for water, the Everglades have been artificially flooded during recent springs, resulting in the inundation of many alligator nests and the destruction of their eggs.—*Richard Milner*



Photograph by Chris Johns

Tony Stone Images

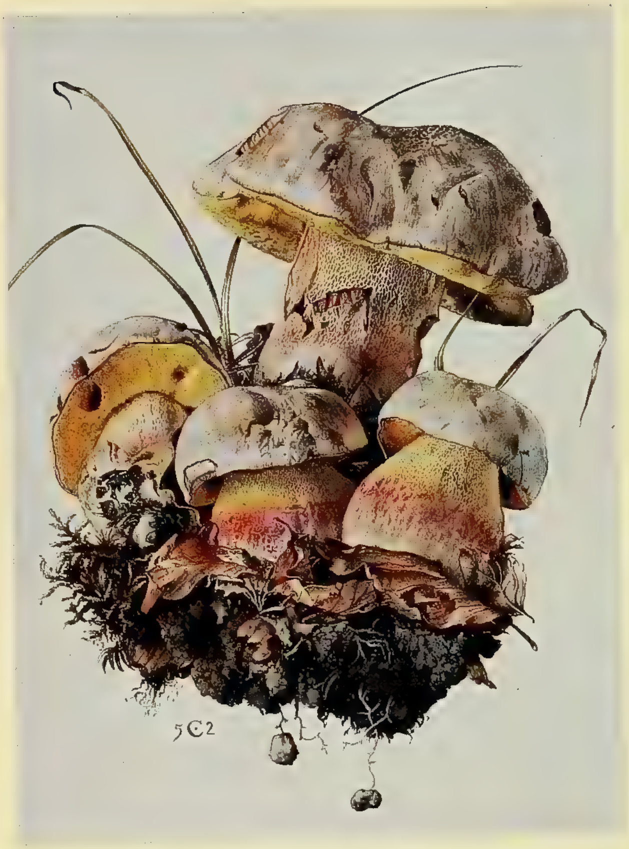
AT THE AMERICAN MUSEUM OF NATURAL HISTORY

IMAX IN SPACE

Two new IMAX films will open on Saturday, July 1. The human–robot partnership in space exploration is the focus of *Destiny in Space*. Narrated by Leonard Nimoy (*Star Trek*'s Mr. Spock), the film uses footage from nine shuttle flights, images from the Hubble space telescope, and computer imaging to take viewers on a journey to the far reaches of the universe. Daily showtimes are 10:30 and 11:30 A.M., and 1:30 and 3:30 P.M. *Titanica* follows an international scientific team as it explores the wreck of the *Titanic*, which sank in the North Atlantic off Newfoundland in April 1912. Daily showtimes are 12:30, 2:30, and 4:30 P.M. *Destiny in Space* and *Titanica* will be presented as a double feature on Friday and Saturday evenings at 6:00 and 7:30 P.M. A $24 ($22 for members) dinner/theater package includes Museum admission, IMAX double feature, and dinner in the Garden Cafe. Call (212) 769-5350 for information about the package and for reservations.

THE FOSSIL TRAIL

Ian Tattersall, author of the recently published *The Fossil Trail* and chairman of the Museum's Department of Anthropology, will give a talk on Thursday, July 6, on the subject of human fossil discoveries. Tattersall, who headed up the team that designed the Museum's Hall of Human Biology and Evolution, offers an insider's perspective on how fossil finds through time have been interpreted—and misinterpreted—in term
human evolution. The lec
will begin at 7:00 P.M. in
Kaufmann Theater. Call (
769-5606 for information.



*Mushrooms (*Boletus aestivalis*), a gouache by Claus Caspari, 1952*

FLORA PORTRAYED

One hundred and thirty-six botanical illustrations from Carnegie-Mellon University's Hunt Institute for Botanical Documentation will be on display in Gallery 77 from Friday, July 14, through Monday, January 15. The exhibition, "Flora Portrayed," includes works ranging from the Renaissance, when modern botany first developed, to the present. Among the artists featured are Johann Theodore de Bry (1561–1623), Maria Sibylla Merian (1647–1717), Pierre-Joseph Redouté (1759–1840), Augusta Innes Withers (1827–1865), and Claus Caspari (1911–1980). Highlighted are nineteenth- and twentieth-century watercolors and illustrations of orchids.

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bans, a vast mangrove sw
between India and Bangl
along the Bay of Bengal.
lecture, starting at 7:00 P.
the Kaufmann Theater, wi
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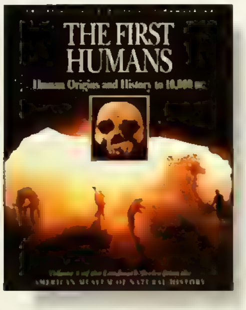
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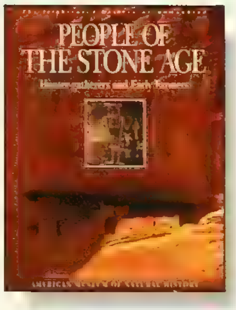
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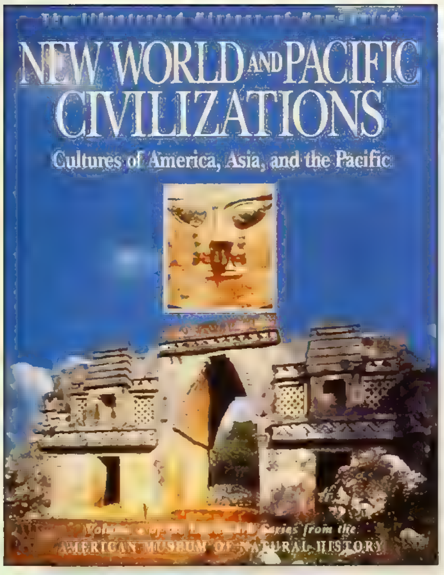
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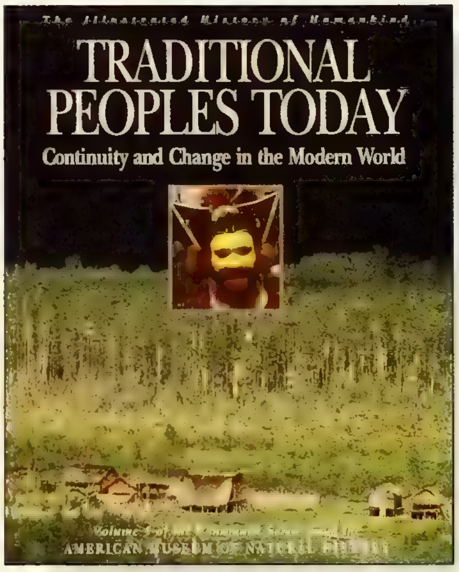
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It's yo, ho, ho and a whole lot of fun for fourth graders at Mesa Elementary in Shiprock, New Mexico. Because they're off on a treasure hunt – thanks to the lesson plan created by their teacher Margaret Tuthill.

Margaret starts with excerpts from Robert Louis Stevenson's classic novel, *Treasure Island*, to get them in the pirating mood. Then, they actually create their own buried treasure maps. During the map creation process, Margaret covers the entire curriculum including history, language arts, math, social studies, art and interpersonal communication. And, of course, geography.

She believes that her treasure hunt lesson plan "opens their eyes to the world." Best of all, they have a great time, which makes teaching and learning an adventure.

Thanks Margaret, for putting innovative lesson plans like this on the map. State Farm is pleased to donate $5,000 in your name to Mesa Elementary. (It's buried under the cottonwood tree, behind the rock, ten paces to your left.)

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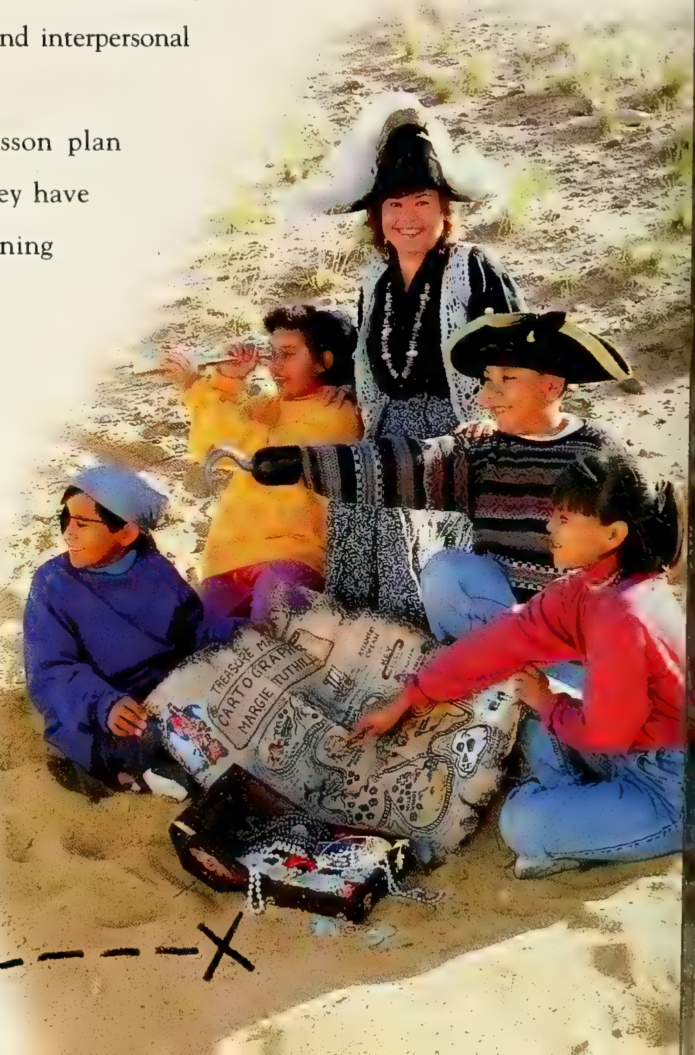

NATURAL HISTORY

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"We have the chance to save one of the last unspoiled ecosystems on our planet."

George Schall

George Schaller, science director of International Programs for the Wildlife Conservation Society, has spent four decades in rugged places, studying wildlife, and fighting for its survival. Now Schaller and his Chinese and Tibetan colleagues have helped establish a huge reserve in the Chang Tang.

There, Tibetan antelope and wild yak can roam free and the nomads can maintai their traditional culture.

"If we don't protect the Chang Tan now, the magnificent species found her could soon vanish forever," says Schaller.

"Working in remote areas like th Tibetan plateau, the right equipment i imperative," he says. "That's one reaso I've worn a Rolex for over fifteen years."

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The Dallas Morning News

RS DEFEAT MIGHTY DUCKS 4-1 IN ANAHEIM, PAGE 1B.

Bonds backed for lake, Hisp

Residents also seek zoo, library fund

By Sylvia Martinez

official visits U.S., to defeat Russia

THIS CLASS DOESN'T JUST STUDY CURRENT EVENTS. THEY MAKE THEM.

Kate Collins does more than prepare her seventh and eighth grade geography classes for the future. She prepares them for the present. All in a lesson she gave her students concerning a dying Dallas landmark – White Rock Lake, a lake that's suffering from the effects of pollution and silting.

Kate had her kids carefully study everything about White Rock Lake. But they looked at more than just the lake's geography. They investigated its ecology as well as the lake's environment. Then they devised a plan of action to save the troubled body of water which they chronicled in a documentary they produced for cable TV.

But the kids didn't stop there. The assignment really came to fruition during a visit to the Dallas City Council, where the kids urged support for $9 million to dredge White Rock Lake. And happily for the kids, as well as for the community, the Dallas City Council eventually approved it.

So it's only natural that State Farm honors Kate with the Good Neighbor Award, along with $5,000 to be donated in her name to St. Monica Catholic School in Dallas, Texas.

STATE FARM INSURANCE

GOOD NEIGHBOR AWARD

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The Good Neighbor Award was developed in cooperation with the National Council for Geographic Education.
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The 400 inhabitants of Ostional, Costa Rica, are subsistence farmers and *hueveros*, collectors of turtle eggs, who have always known about the local *arribada*. But in 1966 Costa Rica outlawed the taking of sea turtle eggs. "Harvesting" became "poaching."

The villagers, clannish and suspicious of the outside world in the best of times, became secretive and hostile. Enforcement to prevent poaching was nearly impossible, and scientific study of the turtle population was fraught with danger. "The villagers threatened to beat us up," recalled marine biologist Jorge Ballestero. Today, after a remarkable revolution in attitudes, Ballestero is paid by those same villagers to advise them on the management of Ostional's turtle population. It has been a hopeful and profound social change—a cooperative effort of scientists, villagers, conservationists, and politicians to work out a management plan that balances profit and protection. Since 1987, the residents of Ostional have legally harvested turtle eggs, governed by regulations that, as far as I could observe, they absolutely obey. "The point is that these regulations were not imposed upon them by the government," Jorge Ballestero told me. "They, with scientists and others, formulated them. Now they speak of 'our' turtles and they are really concerned to preserve the turtles for the future."

An arribada*—the mass arrival of female sea turtles on a nesting beach—is a sight like no other on Earth. Fred Bruemmer's photographic essay on the arrival of more than 150,000 olive ridleys on a Pacific beach in Costa Rica begins on page 36.*

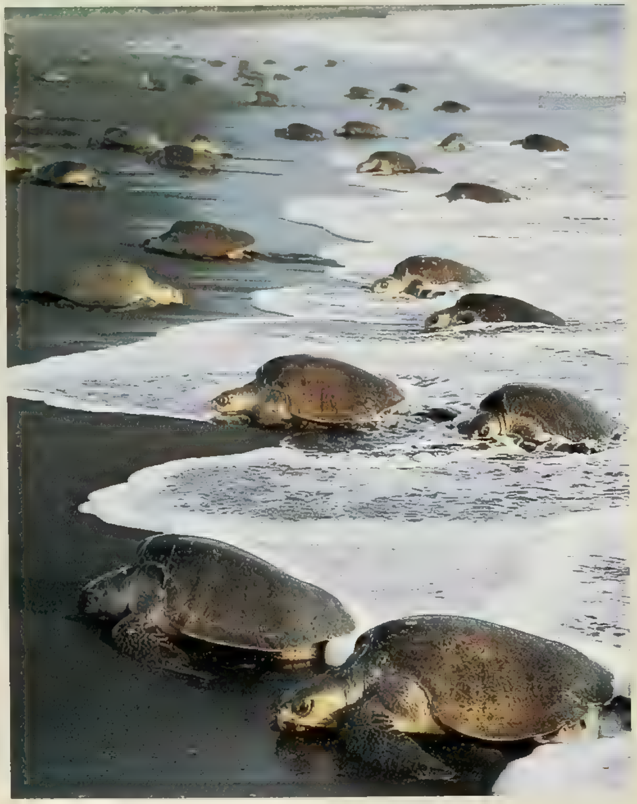
The villagers see to it that the the turtle beach is kept clean and that arriving turtles flipped by surf are righted. Turtles pierced at sea by shark hooks are rescued, if possible, and those enmeshed in nets are freed and released. The beach is constantly patrolled; horseback riders and vehicles are forbidden.

When, about six weeks after the eggs are laid, the hatchlings emerge—small, vulnerable, and tempting morsels for predators—men, women, and children collect them and carry them to the sea. On other nesting beaches, hatchling survival rate is only 1 or 2 percent; at Playa Ostional it is 8 to 12 percent. Each season the villagers take about 10 percent of the 30 million eggs laid at Ostional. But their protection of both adult and hatchling turtles more than compensates for this harvest.

Turtle eggs are the basis of the village economy, bringing in annual revenues of about $95,000. Of this, the government takes 20 percent. Of the remainder, 70 percent goes to members of the village association as payment for their work, and the other 30 percent pays for the full-time resident biologist, the administrators, and the patrols that guard the turtle beach day and night against animal and human predation.

After the *arribada* I witnessed, the 100 members of the association each received 13,000 colones (about $86.00), a lot of money in a region where the daily salary of a farm worker is 500 colones (about $3.30). With the turtle egg money, the people of Ostional have built a health center, an addition to their school, and a turtle research station. In 1994, electricity finally reached the village, but there are still no street lights because the villagers chose not to disturb the turtles with them. During turtle season the few houses near the beach are heavily shuttered lest hatchlings become confused and, attracted by the light, head inland, away from the saving sea.

Perhaps the most important result of this large and well-controlled harvest is that it nearly saturates the market. The legal eggs are cheap (150 colones a dozen, or about one dollar in San José, Costa Rica's capital), and they significantly reduce the demand for the eggs of such threatened species as the green turtle and giant leatherback. Are there concerns about the olive ridley's future? Yes. With so few nesting beaches of such productivity left in the world, the dangers from storms, epidemics, or genetic inbreeding are always present. But barring such disasters, the managed harvest at Ostional helps to protect not only the olive ridleys but all species of sea turtles on the Atlantic and Pacific beaches of Costa Rica.—*Fred Bruemmer*



For olive ridleys, new prospects for survival lie in cooperation between scientists and local villagers.
Fred Bruemmer

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Cover: Probing a muttonbird burrow on an island off Tasmania, an amateur muttonbirder hunting for chicks drives an adult bird out of a second entrance. Story on page 24. *Photograph by Esther Beaton; Terra Australis Photo Agency.*

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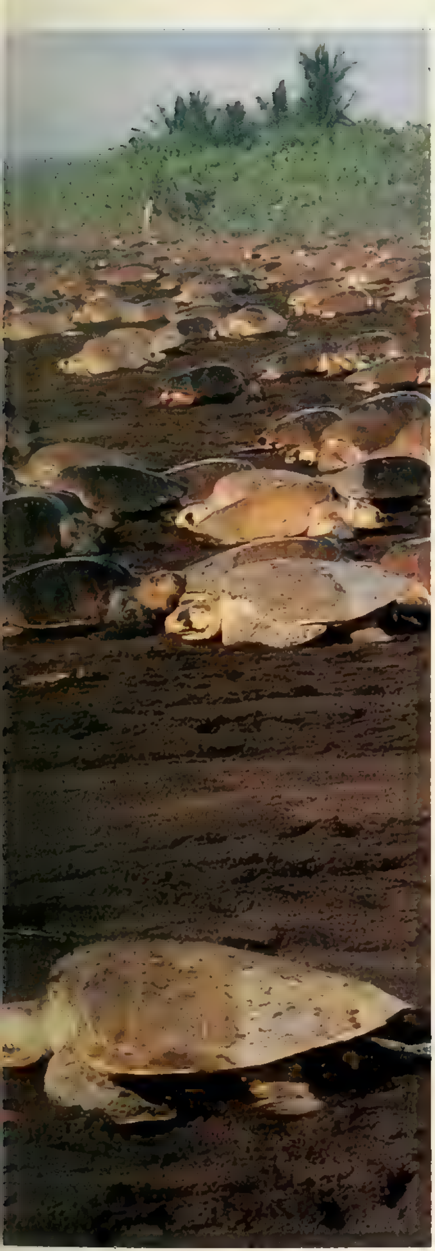

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La Arribada

Text and photographs by Fred Bruemmer

On the coast of Costa Rica, villagers preserve—and profit from—the greatest gathering of sea turtles in the world.

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Photographs by Sylvia Plachy

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Our pets give us a personal connection to nature—one we often find difficult to part with.

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Oviraptor Fan Club

Hip-hip-hooray! After undergoing several years of restoration, the dinosaur halls are reopening. And what better way to announce the return of the halls than by a special issue of *Natural History* ("Dinosaurs: How We Know What We Know," June 1995).

Although many readers may be disappointed because there was no article focusing on *Tyrannosaurus* or other "carnosaurs," you selected a much better theropod to receive the honor of being placed on the cover. That's right, I am talking about *Oviraptor philoceratops*. *Oviraptor* has always been my favorite saurischian, even back in those dark days when it was most commonly depicted as—gasp!—a horned ornithomimid. Thank you for liberating this evolutionary marvel from relative obscurity.

Christian Kammerer
Port St. Lucie, Florida

English Plants, Latin Dinosaurs

Even though I am a professional scientist, I am often stumped whenever Robert Mohlenbrock's "This Land" articles mention plants from an area I'm unfamiliar with. For some unknown reason, when it comes to plants, scientific names evidently are editorially beyond the pale; they must be replaced by common names or be newly christened, often with a mere translation of the scientific term.

Now comes an entire issue devoted to dinosaurs! Common names for them? Oh No! Any grade-school kid who can pronounce Mighty Morphin Power Ranger has no trouble with *Triceratops*, *Archaeopteryx*, *Patagopteryx* or *Mononykus*. We botanists are insulted. Can it be that children must be protected from botanical names? Or is it their parents?

William A. Weber
University of Colorado at Boulder

Natural History is written for the general reader, so we urge our authors to use common names for living things, whether plant or animal. If no common name is known, we opt for scientific nomenclature. Dinosaurs seem to be a special case in which the scientific and common names are one and the same.—*Eds.*

But Define Your Terms

I enjoyed the articles about dinosaurs in your June 1995 issue. However, I wish the authors of "Why Cladistics?" had defined the terms *saurischian* and *ornithischian* instead of assuming that the layman knows what they mean. Because of the prefix *ornith*, I thought the latter term referred to the branch on which modern-day birds are found. But on page 33, I learned that "birds . . . contribute to the variety of the saurischian hall" and on page 35 (and from the diagram on page 34) that the saurischian branch includes the "oldest-known bird, Archaeopteryx."

I would appreciate an explanation of these terms.

Susan Wallenstein
Spring Valley, New York

Lowell Dingus replies: The term *ornithischian* does mean "bird-hipped," and the group was so named because earlier scientists noted the resemblance between the backward-pointing pubis of this group of dinosaurs and that of a modern bird. However, we have subsequently learned that birds share many more derived features with saurischian dinosaurs, such as the grasping hand that eventually evolved into the wing and the distinctively built hind foot with three principal toes. The backward-pointing pubis of modern birds was the result of convergent (or independent) evolution that occurred late within the saurischian line.

Why No Eyes?

"Cosmic Windows," by Neil de Grasse Tyson ("Universe," June 1995) was an enjoyable tour of the electromagnetic spectrum, but it missed a golden opportunity to put visible light in perspective.

After carefully describing each of the "invisible" parts of the spectrum, fro radio waves to gamma rays, the autho rushes through the band between infrare and ultraviolet, remarking: "The energ emitted by the sun . . . peaks in the visibl part of the spectrum, as does the sensiti ity of the human retina."

Isn't there a causal reason for thi match? Humans, and other animals th are active on Earth's surface during day light, evolved under the sun. Our eyes ar most sensitive to the electromagnetic rad ation that reaches us from the sun becaus we can function best by using the mo plentiful frequencies.

William F. Fall
Arlington, Virgin

Neil de Grasse Tyson replies: You rais interesting and correct points about th correspondence between the human ey and the sun's spectral energy distributio The first draft of "Cosmic Windows" ha much more about the evolution of th human eye, but the topic acquired a life its own and rapidly derailed the scientifi narrative. The subject may one day appe as its own essay.

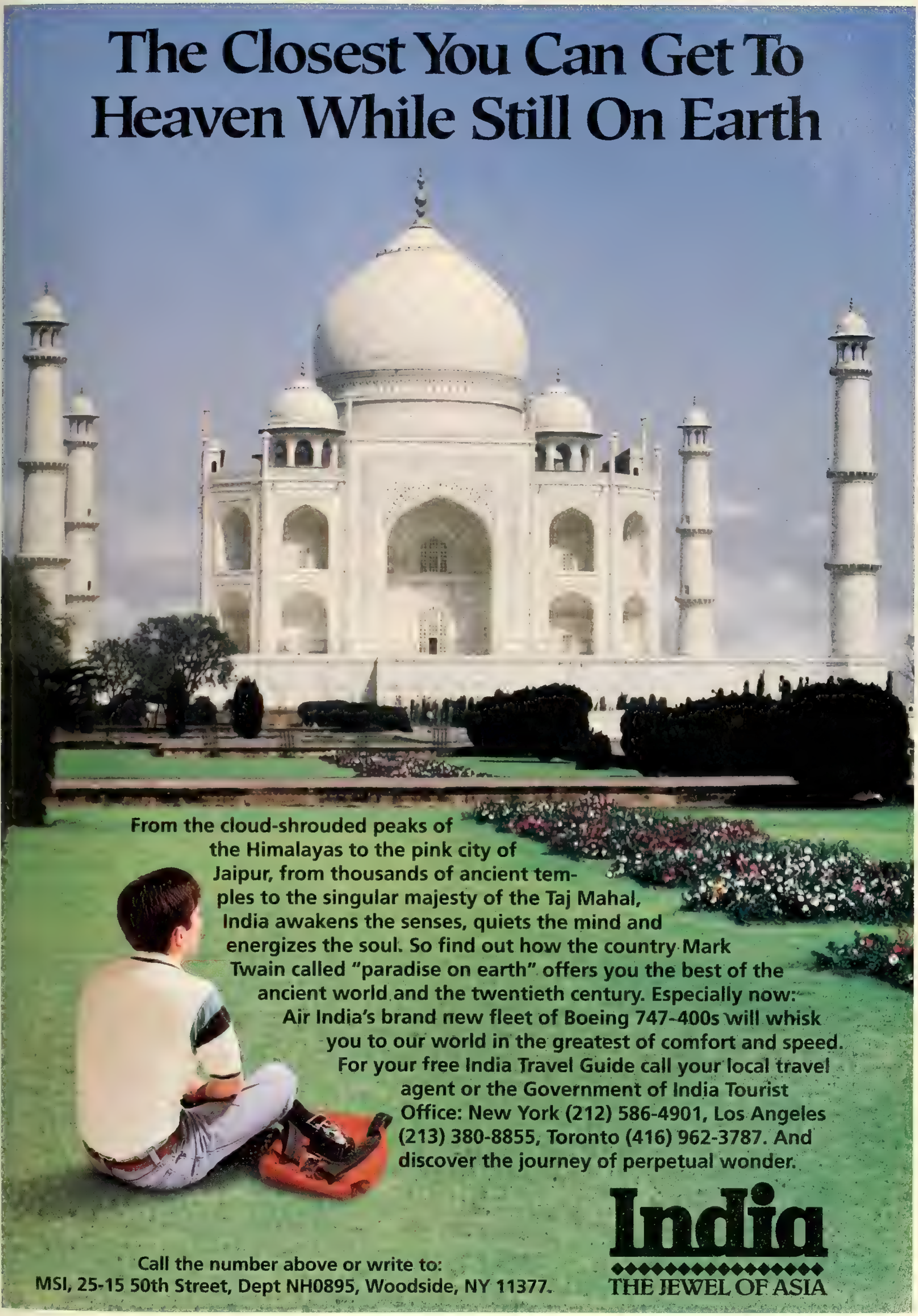
How to Play Cricket

As an Englishwoman currently watc ing the 1995 Test Series between m country and the West Indies, I enjoye reading about the 1950 Test Series i Samuel Wilson's article, "Cricket in th Blood" (May 1995).

However, I must take him to task in th section on how to play the game. A crick ball is never "thrown" toward a batsman. is bowled. Throwing involves bending th arm; at the point of releasing a cricket ba a bowler's arm must be perfectly straigh

To suggest that a bowler threw a ball t ward a batsman is one of the gravest acc sations you could make: to throw would b to cheat, and "that's not cricket" (an En lish phrase for "fair play"). Sorry, I ju couldn't help myself.

Eileen Colli
Birmingham, Englan



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Boyle's Law and Darwin's Details

Where the chemist saw God, the evolutionist saw contingency and chance

by Stephen Jay Gould

Two scenes from Florence beautifully illustrate the power of scientific revolutions to alter our view of the geometry of existence. A painting by the fifteenth-century artist Michelino hangs in the great cathedral of Santa Maria del Fiore. Entitled *Dante e il suo poema* (Dante and His Poem, that is, *The Divine Comedy*), it shows the entire universe on a single canvas. The earth occupies the center, symbolized by the city of Florence, with Dante in the middle and Brunelleschi's magnificent dome for the cathedral to his left (an anachronism, to be sure, for Dante died in 1321 and Brunelleschi raised the great dome a century later). At Dante's right, the souls of the damned move downward to the Inferno, while those ultimately to be saved slowly mount the spire of Purgatory. The seven semicircles at the top are the seven planets of Ptolemy's earth-centered system (the five visible planets plus the sun and the moon). The farthest realm of the fixed stars occupies the upper corners.

If we take a short walk to the Franciscan church of Santa Croce we find the tomb of Galileo. The face of his statue looks upward toward his expanded heavens, and he holds a telescope in his right hand. His left hand envelops the small and insignificant sphere of the earth. In two centuries (Galileo died in 1642), the earth had been displaced from centrality in a limited and subservient universe to peripheral status as a little hunk of stone suspended in the midst of inconceivable vastness.

In last month's essay, I used a famous quotation from Freud to argue that scientific revolutions are completed, not when people accept the physical reconstruction of reality thus implied, but when they also own the consequences of this new universe for a demoted view of human status. Freud claimed that all important scientific revolutions share the ironic property of deposing humans from one pedestal after another of previous self-assurances about our exalted cosmic status. Therefore, all great revolutions smash pedestals and inspire resistance for the obvious reason that we accept such demotions only grudgingly. Freud identified two revolutions as paramount—Copernicus to Galileo on the nature of the heavens and Darwin on the status of life. I then argued that Darwin's revolution remains incomplete because we spin doctor the results of evolution to misread the process as a predictable accumulation of progressive events, leading sensibly to the late appearance of human intelligence as a culmination.

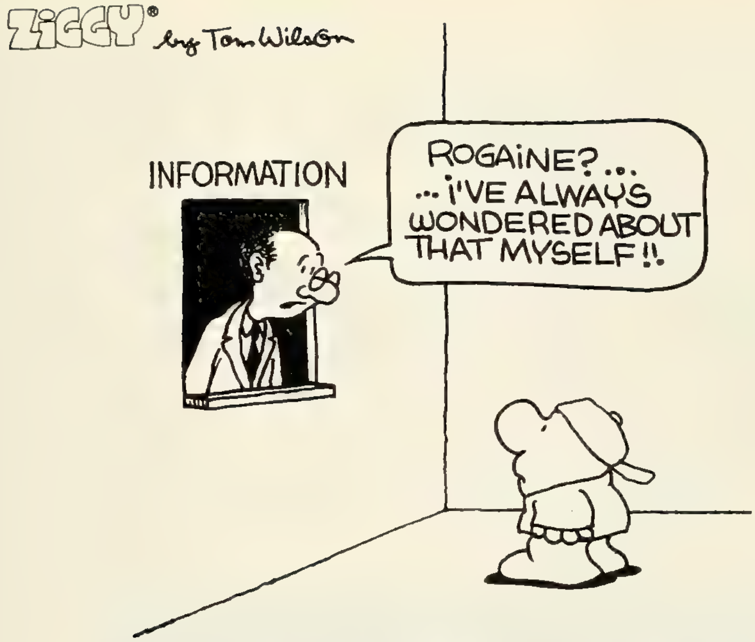
Although we have yet to make our peace with Darwin, the first revolution of cosmic realignment passed quickly to public acceptance. In 1633, Galileo was tried by the Inquisition in Rome and forced to abjure his belief in the sun-centered Copernican system. He spent the rest of his life under house arrest on his estate at Arcetri, near Florence, where he died in 1642. In the same year, Robert Boyle, then a wealthy teenager on his grand tour of Europe but soon to become a great physicist and chemist in his own right, visit Florence and read Galileo's *Dialog Concerning the Two Chief World Syste* just as the master lay dying nearby Arcetri.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University. He is also Frederick P. Rose Honorary Curator in Invertebrates at the American Museum of Natural History.

In 1688, as an elderly man himse Robert Boyle wrote a famous treatise science and religion entitled *A disquisiti about the final causes of natural thing wherein it is inquir'd, whether, and (if all) with what cautions, a naturali should admit them?* In this work, just tv generations after Galileo's death, Boy demonstrates that the pedestal-smashi implications of the heliocentric view h already been articulated and accepte thus completing the first revolution Freud's crucial sense. (I regard this timi as important because one might claim th Galileo has triumphed, while Darwin r mains in limbo, simply because pedest smashing takes centuries and Galileo h a 200-year head start. But if the pedes crumbled during Galileo's own centu then we have had more than enough tin for Darwin—and our failure to smash th second pedestal must record its great durability in our unwilling psyches.)

Boyle asks whether the existence a regular motion of the sun and moon pr vide evidence of God's creative power a benevolent action. He begins by ridiculi those who would argue for the old geoce tric system because God made everythi for human benefit:

> I dare not imitate their boldness, that affir that the sun and moon, and all the stars, a other celestial bodies, were made solely f the use of man; . . . as when they argue, th the sun and other vast globes of light, oug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After 1 year of use, almost half of the men who continued using *Rogaine* rated their regrowth as moderate (40%) to dense (8%). Thirty-six percent reported minimal regrowth. The rest (16%) had no regrowth.

Side effects? About 7% of those who used *Rogaine* had some itching of the scalp. (Roughly 5% of those on the placebo reported the same minor irritations.) *Rogaine* should only be applied to a normal, healthy scalp (not sunburned or irritated).

Make a commitment to see results.

Studies indicate it usually takes *at least 4 months of twice-daily treatment before there is evidence of regrowth.* If you're younger, have been losing your hair for a shorter period of time, and have less initial hair loss, you're more likely to have a better response.

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ROGAINE Topical Solution is a prescriptiomedicine for use on the scalp that is used to treat a type of hair loss in men and women known as androgenetic alopecia: hair loss of the scalp vertex (top or crown of the head) in men and diffuse hair loss or thinning of the front and top of the scalp in women. ROGAINE is a topical form of minoxidil, for use on the scalp.

How effective is ROGAINE?
In men: Clinical studies with ROGAINE of over 2,300 men with male pattern baldness involving the top (vertex) of the head were conducted by physicians in 27 US medical centers. Based on patient evaluations of regrowth at the end of 4 months, 26% of the patients using ROGAINE had moderate to dense hair regrowth compared with 11% who used a placebo treatment (no active ingredient). No regrowth was reported by 41% of those using ROGAINE and 58% of those using a placebo. By the end of 1 year, 48% of those who continued to use ROGAINE rated their hair growth as moderate or better.

In women: A clinical study of women with hair loss was conducted by doctors in 11 US medical centers. Based on patients' self-ratings of regrowth after 32 weeks, 59% of the women using ROGAINE rated their hair regrowth as moderate (19%) or minimal (40%). For comparison, 40% of the women using placebo (no active ingredient) rated their hair regrowth as moderate (7%) or minimal (33%). No regrowth was reported by 41% of the group using ROGAINE and 60% of the group using placebo.

How soon can I expect results from using ROGAINE?
Studies show that the response time to ROGAINE may differ greatly from one person to another. Some people using ROGAINE may see results faster than others; others may respond with a slower rate of hair regrowth. You should not expect visible regrowth in less than 4 months.

How long do I need to use ROGAINE?
ROGAINE is a hair-loss treatment, not a cure. If you have new hair growth, you will need to continue using ROGAINE to keep or increase hair regrowth. If you do not begin to show new hair growth with ROGAINE after a reasonable period of time (at least 4 months), your doctor may advise you to discontinue using ROGAINE.

What happens if I stop using ROGAINE? Will I keep the new hair?
Probably not. People have reported that new hair growth was shed after they stopped using ROGAINE.

How much ROGAINE should I use?
You should apply a 1-mL dose of ROGAINE twice a day to your clean dry scalp, once in the morning and once at night before bedtime. Wash your hands after use if your fingers are used to apply ROGAINE. ROGAINE must remain on the scalp for at least 4 hours to ensure penetration into the scalp. Do not wash your hair for at least 4 hours after applying it. If you wash your hair before applying ROGAINE, be sure your scalp and hair are dry when you apply it. *Please refer to the Instructions for Use* in the package.

What if I miss a dose or forget to use ROGAINE?
Do not try to make up for missed applications of ROGAINE. You should restart your twice-daily doses and return to your usual schedule.

What are the most common side effects reported in clinical studies with ROGAINE?
Itching and other skin irritations of the treated scalp area were the most common side effects directly linked to ROGAINE in clinical studies. About 7 of every 100 people who used ROGAINE (7%) had these complaints.

Other side effects, including light-headedness, dizziness, and headaches, were reported both by people using ROGAINE and by those using the placebo solution with no minoxidil. You should ask your doctor to discuss side effects of ROGAINE with you.

People who are extra sensitive or allergic to minoxidil, propylene glycol, or ethanol should not use ROGAINE.

ROGAINE Topical Solution contains alcohol, which could cause burning or irritation of the eyes or sensitive skin areas. If ROGAINE accidentally gets into these areas, rinse the area with large amounts of cool tap water. Contact your doctor if the irritation does not go away.

What are some of the side effects people have reported?
ROGAINE was used by 3,857 patients (347 females) in placebo-controlled clinical trials. Except for dermatologic events (involving the skin), no individual reaction or reactions grouped by body systems appeared to be more common in the minoxidil-treated patients than in placebo-treated patients.

Dermatologic: irritant or allergic contact dermatitis—7.36%; **Respiratory:** bronchitis, upper respiratory infection, sinusitis—7.16%; **Gastrointestinal:** diarrhea, nausea, vomiting—4.33%; **Neurologic:** headache, dizziness, faintness, light-headedness—3.42%; **Musculoskeletal:** fractures, back pain, tendinitis, aches and pains—2.59%; **Cardiovascular:** edema, chest pain, blood pressure increases/decreases, palpitations, pulse rate increases/decreases—1.53%; **Allergic:** nonspecific allergic reactions, hives, allergic rhinitis, facial swelling, and sensitivity—1.27%; **Metabolic-Nutritional:** edema, weight gain—1.24%; **Special Senses:** conjunctivitis, ear infections, vertigo—1.17%; **Genital Tract:** prostatitis, epididymitis, vaginitis, vulvitis, vaginal discharge/itching—0.91%; **Urinary Tract:** urinary tract infections, renal calculi, urethritis—0.93%; **Endocrine:** menstrual changes, breast symptoms—0.47%; **Psychiatric:** anxiety, depression, fatigue—0.36%; **Hematologic:** lymphadenopathy, thrombocytopenia, anemia—0.31%.

ROGAINE use has been monitored for up to 5 years, and there has been no change in incidence or severity of reported adverse reactions. Additional adverse events have been reported since marketing ROGAINE and include eczema; hypertrichosis (excessive hair growth); local erythema (redness); pruritus (itching); dry skin/scalp flaking; sexual dysfunction; visual disturbances, including decreased visual acuity (clarity); increase in hair loss; and alopecia (hair loss).

What are the possible side effects that could affect the heart and circulation when using ROGAINE?
Serious side effects have not been linked to ROGAINE in clinical studies. However, it is possible that they could occur if more than the recommended dose of ROGAINE were applied, because the active ingredient in ROGAINE is the same as that in minoxidil tablets. These effects appear to be dose related; that is, more effects are seen with higher doses.

Because very small amounts of minoxidil reach the blood when the recommended dose of ROGAINE is applied to the scalp, you should know about certain effects that may occur when the tablet form of minoxidil is used to treat high blood pressure. Minoxidil tablets lower blood pressure by relaxing the arteries, an effect called vasodilation. Vasodilation leads to fluid retention and faster heart rate. The following effects have occurred in some patients taking minoxidil tablets for high blood pressure:

Increased heart rate: some patients have reported that their resting heart rate increased by more than 20 beats per minute.

Salt and water retention: weight gain of more than 5 pounds in a short period of time or swelling of the face, hands, ankles, or stomach area.

Problems breathing: especially when lying down; a result of a buildup of body fluids or fluid around the heart.

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In animal studies, minoxidil, in much larger amounts than would be absorbed from topical use (on skin) in people, has caused important heart-structure damage. This kind of damage has not been seen in humans given minoxidil tablets for high blood pressure at effective doses.

What factors may increase the risk of serious side effects with ROGAINE?
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ROGAINE should be used only on the balding scalp. Using ROGAINE on other parts of the body may increase minoxidil absorption, which may increase the chances of having side effects. You should not use ROGAINE if your scalp is irritated or sunburned, and you should not use it if you are using other skin treatments on your scalp.

Can people with high blood pressure use ROGAINE?
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People who use ROGAINE should see their doctor 1 month after starting ROGAINE and at least every 6 months thereafter. Stop using ROGAINE if any of the following occur: salt and water retention, problems breathing, faster heart rate, or chest pains.

Do not use ROGAINE if you are using other drugs applied to the scalp such as corticosteroids, retinoids, petrolatum, or agents that might increase absorption through the skin. ROGAINE is for use on the scalp only. Each 1 mL of solution contains 20 mg minoxidil, and accidental ingestion could cause unwanted effects.

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Pregnant women and nursing mothers should not use ROGAINE. Also, its effects on women during labor and delivery are not known. Efficacy in postmenopausal women has not been studied. Studies show the use of ROGAINE will not affect menstrual cycle length, amount of flow, or duration of the menstrual period. Discontinue using ROGAINE and consult your doctor as soon as possible if your menstrual period does not occur at the expected time.

Can ROGAINE be used by children?
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to be in perpetual motion to shine upon th earth; because, they fancy, 'tis more convenient for man, that those distant bodies, thar that the earth, which is his habitation should be kept in motion.

Boyle then invokes the smashe pedestal more directly to claim that Go would not create something so huge as th sun only to illuminate such a tiny and inconsequential body as the earth:

> But, considering things as mere naturalists it seems not very likely, that a most Wis Agent should have made such vast bodies as the sun and the fixed stars, especially i we suppose them to move with that inconceivable rapidity that vulgar astronomers d and must assign them; only or chiefly to illuminate a little globe that without hyperbole is but a physical point in comparison o the immense spaces comprised under th name of heaven.

Writing 150 years before Darwin, w would not expect Boyle to be assaultin the second pedestal or even questionin the creationist view of life at all. Rather, dedicate this essay to demonstrating tha Boyle's particular view of natural religio provides a distinctively English insigh into the historical traditions that make th Darwinian pedestal so impervious to demolition. I then show that Darwin's philosophical radicalism lies best expose when we view the theory of natural selection as a direct and purposeful assaul upon Boyle's natural theology.

Robert Boyle (1627–91) belonged to noble and wealthy Anglo-Irish family (hi father was the first earl of Cork). Afte studying at Eton and living abroad for several years, Boyle spent his most scientifically productive decade at Oxfor (1656–68), where he constructed an ai pump and performed his major experiments on the properties of gases. (Hi most famous result, Boyle's law, state that, at a constant temperature, the pressure of a given quantity of gas varies inversely as its volume—I trust we all remember that from high school physics!) I his most famous work, the *Sceptica Chymist* (1661), Boyle attacked the Aristotelian theory of four elements (earth, ai fire, and water) and developed an important corpuscular theory of matter. (He di not postulate different kinds of basic elements, as later validated and established i the periodic table, but rather argued tha properties of different substances aros from variation in the motion and organization of primary particles.)

Boyle moved permanently to Londo in 1668, where he continued his organiza tional work as a founder of the Royal Society (still Britain's leading scientific establishment) and labored for many other causes close to his heart (he was, for example, the governor of the Society for the Propagation of the Gospel in New England).

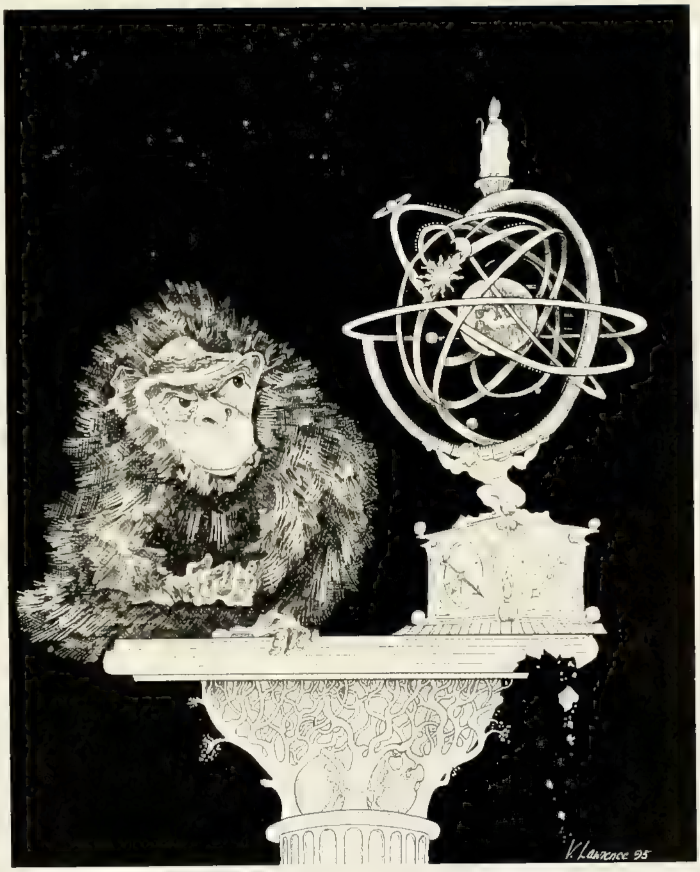
In science, Boyle's main reputation rested upon his stern defense of mechanism and his abjuration of Aristotelian forms and essences. The *Dictionary of Scientific Biography* describes his fundamental philosophy in these terms:

> [Boyle was] a profound believer in the need to establish an empirically based, mechanistic theory of matter and in the possibility of establishing a scientific, rational, theoretical chemistry. . . . Boyle was long remembered as "the restorer of the mechanical philosophy" in England. . . What mattered most to him was destroying all Aristotelian forms and qualities . . . and substituting for them rational, mechanical explanation in terms of what he called "those two grand and most catholic principles, matter and motion."

But Boyle had another interest as strong as his devotion to science—his orthodox Protestant beliefs and his passionate commitment to the cause of religion. Of all the scientists in Newton's orbit, Boyle was the most conventionally and sincerely devout. Moreover, Boyle did not consider religion as merely a private matter. He wrote as much about theology as about science, and he composed several treatises on the potentially harmonious relationship of these two disciplines, including the work analyzed in this essay.

Such a statement may seem contradictory according to a blinkered modern view that regards all religion as inherently mystical, and considers the mechanistic components of science as antithetical to such a notion of higher reality. But Boyle's view of God, widely shared by Newton and most of his scientific contemporaries, neatly married mechanism and religion into a coherent system that granted high status to both sides. Boyle's God is a masterful, mechanical clockwinder who created the universe with all its laws so perfectly tuned and contrived at the outset that all future history could unfold without further miraculous intervention (although neither Boyle nor Newton wanted to constrain God to his initial decisions, and certainly granted him the right to fashion a miracle now and then, whenever his ineffable wisdom so decreed). Boyle wrote:

> The most wise and powerful Author of Nature, whose piercing sight is able to penetrate the whole universe, and survey all the parts of it at once, did at the beginning of things, frame things corporeal into such a system, and settled among them such laws of motion, as he judged suitable to the ends he proposed to himself in making the world. And as by virtue of his vast and boundless intellect that he at first employed, he was able not only to see the present state of things he had made, but to foresee all the effects. . . . Nor is this doctrine inconsistent with the belief of any true miracle; for, it supposes the ordinary and settled course of nature to be maintained, without at all denying, that the most free and powerful Author of Nature is able, whenever he thinks fit, to suspend, alter, or contradict those laws of motion, which he alone at first established.



Vint Lawrence

Since God's constant laws can be discovered and studied by science, and since divine omnipotence lies best exposed in these regularities, God's glory can be apprehended empirically, thus making the study of nature a handmaid to religion, and not at all an adversary.

Boyle's 1688 *Disquisition About the Final Causes of Natural Things* is the classic statement of this English approach to natural theology. It began a tradition that culminated in William Paley's *Natural Theology* of 1802 (one of the most influential books of the nineteenth century, and still required reading at Oxford and Cambridge well into our century) and collapsed with Darwin's *Origin of Species* in 1859. The centerpiece of this tradition lay in the so-called argument from design, or the attempt to identify final causes in nature as proofs not only of God's existence but also of his character in ultimate power and unceasing benevolence (Paley subtitled his work: *Evidences of the existence and attributes of the deity, collected from the appearances of nature*).

To appreciate the power (and ultimate fallacy) of this argument, we must recover some forgotten terminology and explicate the notion of "final cause" in the light of Aristotle's celebrated analysis. (Boyle was no fan of Aristotle's physics, but he followed the master's traditional explication of the categories of causality.) Aristotle proposed that causality included four separate components, as best illustrated in the classic "parable of the house." The stuff of construction counts as a "material cause," for the house will be different (as the three little pigs learned) if the building be of straw, wood, or stone. The mason who puts the pieces together is an "efficient cause." The blueprint is only a plan on paper and does nothing to build the house directly. But without a plan, you only have a pile of stones, so this blueprint counts as a "formal cause." Lastly, without an intended purpose, no one would bother to build at all, so the owner's desire to live in the

Please turn to page 68

The Monogamous Brain

Or, what a small midwestern rodent has taught us about the chemistry of mammalian love

by Thomas R. Insel and C. Sue Carter

Love may be too complex and ineffable a subject for hard science, but recent research into brain chemistry is beginning to show that hormones may have something to do with an aspect of love called attachment. What makes mammals (including ourselves) stick to particular sexual partners or dote upon their own offspring? To find out, we, and a number of other researchers, have been studying a mouse-size rodent called the prairie vole.

A common resident of midwestern grasslands, the prairie vole was singled out because it is exceptionally monogamous, which to biologists means it has a strong and lasting connection to a single mate. Perfect sexual fidelity does not figure in the scientific definition of monogamy, but prairie voles may come pretty close.

Thanks to zoologist Lowell Getz who, with his students at the University of Illinois, has been studying prairie vole natural history for more than thirty years, we have a detailed picture of the social lives of these tiny, brownish gray rodents. Getz recently published data on 249 vole couples that he followed from pairing to separation. Death of one of the partners accounted for 73.5 percent of the separations, while departure of the male accounted for only 10.9 percent. Perhaps most remarkable, when one of the pair died, less than 20 percent of the surviving partners took a new mate. Family attachments were also strong; prairie vole pairs stay together to produce multiple litters, and both parents care for nestlings. After the young are weaned, at about twenty-two days of age, 70 to 75 percent of them remain with the family.

We suspected that, in the prairie vole and other mammals, chemical and physiological processes in the brain were involved in the formation of social bonds. But where would we look for the chemical needle in the haystack? We decided to focus on oxytocin and vasopressin, two hormones manufactured in the hypothalamus, the part of the brain that controls such "primitive" behaviors as feeding, sex, and aggression. Some studies had hinted that oxytocin, well known for its role in inducing the uterine contractions of labor and the milk-ejection reflex of nursing, also seemed to act within the brains of rats and mice to stimulate a mother's interest in her newborn pups. Vasopressin had been associated with some specifically male behaviors, such as the scent marking of territorial boundaries.

Both oxytocin and vasopressin are neuropeptides, compounds that bind to specific targets in the brain, called receptors, where they function like keys fitting into locks. The receptors can be mapped to see what parts of the brain the hormones act on. But to see if the two hormones had a specific role in prairie vole monogamy, we needed something roughly akin to a control group. A perfect candidate was the montane vole, an asocial species that inhabits high meadows and that looks very much like its prairie-dwelling cousin (both are in the genus *Microtus*). Unlike prairie vole families, which share an elaborate system of burrows and feeding tunnels, montane voles live in separate burrows, and males and females are rarely found together in the wild. Males do not participate in raising young, nor do they defend their mates. Mothering is a brief episode

The prairie vole, a burrow-dwelling denizen of midwestern grasslands, forges uncommonly strong bonds with its mate and offspring.

Wendy Shattil/Bob Rozinski

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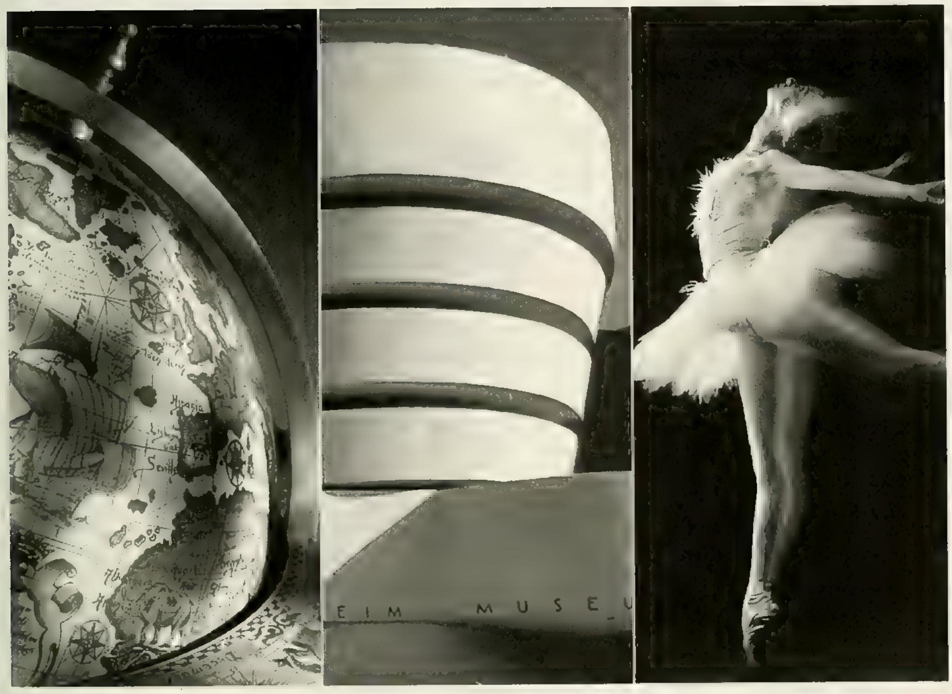

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even for a small mammal; montane vole females abandon their young as soon as sixteen days after giving birth.

With Lawrence Shapiro, then at the National Institute of Mental Health (NIMH) in Poolesville, Maryland, we mapped receptor sites for a number of hormones in both species. While prairie vole and montane vole brain maps were similar for some hormones (such as brain opiates), they differed sharply for oxytocin and vasopressin. And when we compared our results with brain mapping done on other vole species, we found that prairie vole maps resembled those of the pine vole, another monogamous species, while the montane vole maps looked like those of the meadow vole, a polygynous species. Most interesting of all, just after a female montane vole bears young, the pattern of receptor distribution in her brain shifts to resemble that of a female prairie vole.

The brain maps were strong circumstantial evidence that oxytocin and vasopressin were activating entirely different brain circuits in monogamous and polygynous voles, but they didn't establish a cause-and-effect relationship between the hormones and the behavior. An ostensibly unrelated development in another laboratory ultimately helped do that.

Maurice Manning, and his colleagues in the Department of Biochemistry at the Medical College of Ohio in Toledo, developed several oxytocin and vasopressin "antagonists." These compounds chemically resembled those hormones and bound to the appropriate brain receptors but blocked the physiological effects.

If the antagonists could be shown to selectively block an animal's normally monogamous behavior, that would be strong evidence that the oxytocin and vasopressin are crucial for pair bonding. However, we were in no position to perform such experiments in the field.

But sexual and social behaviors can also be studied in the laboratory, and researchers at several sites, including the University of Illinois and the University of Maryland, began to study prairie voles under controlled conditions. At Maryland, Diane Witt made an intriguing discovery about the intensity of prairie vole mating behavior and the long-term bonding that it seems to instill. Witt observed that as soon as female prairie voles became sexually receptive, pairs copulated repeatedly, more than fifty times during a thirty-six- to forty-eight-hour period. After such mating bouts, the social behavior of both males and females changed markedly. Males developed a clear preference for their mates and guarded them ferociously against the approach of rivals. (Both the preference and the ferocity persisted, even when females were experimentally removed by researchers.)

How does mating turn a footloose, fancy-free, and gentle male vole into a committed companion willing to die for its mate? Several lines of evidence, including the mapping studies, implicated either vasopressin or oxytocin in the process, because both are released during copulation.

To test the role of vasopressin in pair bonding, James Winslow, then at the NIMH in Poolesville, gave a vasopressin antagonist to male prairie voles just before they were ready to mate. The pairs still copulated repeatedly and intensely, but afterward the males failed to fend off intruders and showed no preference for their partners. Moreover, the effect was specific to vasopressin—the oxytocin antagonist did not alter either the male's mate guarding or its partner preference.

After intense bouts of mating, male prairie voles develop a clear preference for their mates and guard them ferociously.

When Winslow injected vasopressin into prairie vole males that had been isolated from females, the voles became aggressive and attacked same-sex intruders. If the male received vasopressin and was also exposed to a female, he developed a preference for her over other females, even if the two did not mate.

But what about paternal care of young? Many biologists consider this to be an essential feature of male monogamy. In a recent study, Zuo-Xin Wang, Craig Ferris, and Geert DeVries, of the University of Massachusetts Department of Psychology in Amherst, found that vasopressin increased (and a vasopressin antagonist decreased) the amount of time male prairie voles spent with pups.

Female voles, on the other hand, seemed to have little reaction to vasopressin. Yet after mating, they, too, become more socially exclusive, preferring their mates to unfamiliar males. We know that oxytocin is released during copulation in females of several other small mammals (such as rabbits and rats), and we believe that the hormone is critically important for the development of social preferences in female prairie voles.

Do vasopressin and oxytocin provide the chemistry for human attachment? In fact, we know very little about the hormonal basis of social attachment in our own species. We do know, however, that oxytocin and vasopressin are manufactured in the human brain and bind to receptors there. A British study of male medical students showed that vasopressin is released into the bloodstream during sexual arousal and that oxytocin is released at orgasm. In women, labor and nursing release oxytocin into the blood. But we do not know whether either of these hormones is simultaneously released within the brain to influence our social behavior. (Neuropeptides are large molecules that cannot readily penetrate the blood–brain barrier.)

While oxytocin and vasopressin acting in the hypothalamus seem to virtually mandate social attachments in voles, we cannot make such simple equations for ourselves. In large-brained primates like us, the effects of oxytocin and vasopressin (as well as the many other hormones involved in our sexual and social behavior) are undoubtedly mediated—and perhaps inhibited—by many other factors, especially by the complex activities of our enormous cerebral cortex.

Nonetheless, if oxytocin and vasopressin were shown to play a part in how humans form attachments, they might serve an important therapeutic role for people who suffer from an inability to form social attachments, as in autism or certain forms of schizophrenia. Even as young children, they seem to lack the normal spark of interest in social interaction; and as they grow up, they fail to form normal social bonds. We know very little about either the cause or the treatment of such disorders. Perhaps studies of the brain mechanisms of pair-bond formation in monogamous species will be one of the keys that unlock this and other doors as we try to solve the mystery of human social attachment.

Thomas R. Insel is director of the Yerkes Primate Research Center at Emory University in Atlanta and a professor of psychiatry and behavioral science at the university's medical school. C. Sue Carter is a professor of zoology at the University of Maryland.

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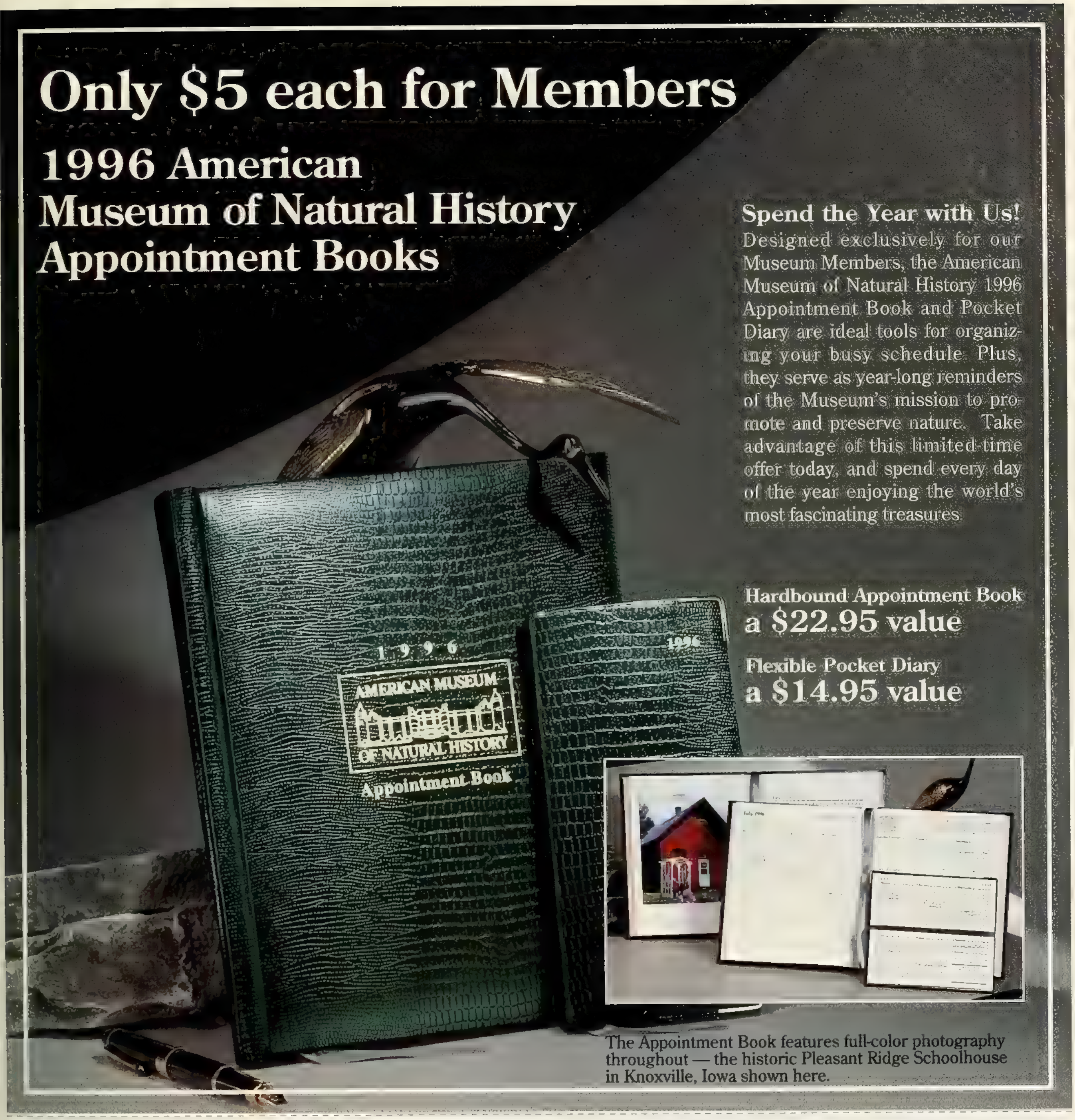

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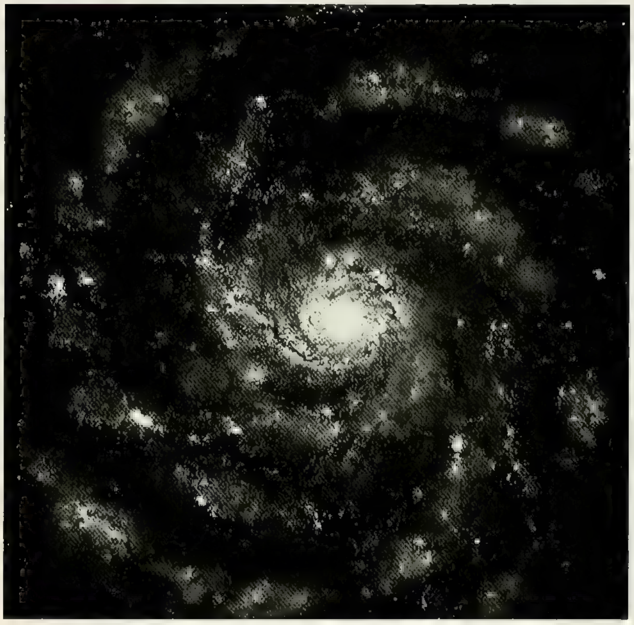
The Milky Way Bar

by Neil de Grasse Tyson

As you probably know, our solar system is part of a large, flattened, spiral-shaped disk of several hundred billion stars known as the Milky Way. In its center—protruding slightly above and below the plane—is the galactic bulge, a dense collection of 10 billion stars. Taken as a whole, the shape of the Milky Way greatly resembles that of a fried egg.

Clues to the Milky Way's general appearance were first obtained by analogy with the shapes of nearby spiral galaxies. These shapes so intrigued American astronomer Edwin Hubble—the well-publicized, orbiting Hubble Space Telescope was named in his honor—that, in the 1920s, he arranged them in a continuous sequence that extended from tightly wound spirals, most of which contain large, round bulges, to loosely wound spirals with small, round bulges. Simple enough. But the inventory of spiral galaxies includes many whose central regions are distinctly bar shaped. Hubble called these galaxies "barred spirals," and found they were otherwise similar to ordinary spirals.

Astrophysicists long assumed that we were living in a symmetrical spiral galaxy with a round bulge at its center; it was a simple and easy explanation of what could be seen, and there were no convincing data to the contrary. But it is nearly impossible for us to know the shape of the central region of a spiral galaxy without the privilege of a "bird's-eye view." Embedded as we are within the Milky Way—our "disadvantage point" in the solar system—we see our own galaxy edge-on. Over the past five years, however, assorted evidence has been amassed showing that the Milky Way's bulge has the shape of a bar. Which leads me to offer some simple advice: If you want to learn the general appearance of something, don't get too close and especially don't go inside—whatever an unborn child may know, it is guaranteed to be ignorant about what its mother looks like.



Before: Our pre-1991 conception of the Milky Way galaxy. Note that the inner region, the galactic bulge, is spherical.

Computer graphics by Dennis Davidson
Source: Richard S. Perkin Library of the Hayden Planetarium

To observe the bulge from inside the disk, one must overcome some of the greatest challenges an astronomer with a telescope may encounter: at over 25,000 light-years away, most of the bulge's stars are hopelessly dim; the brighter stars, although less common, are so tightly packed that until the 1980s, the beginning of the era of digital detectors in astronomy, one star could not be separated from another on a photograph; and thick clouds of obscuring dust in the plane of the Milky Way block most lines of sight to the bulge. This last difficulty can be monstrous; visible light traveling directly from the galactic center to our solar system, for example, is dimmed by a factor of a billion. (Perhaps we shouldn't moan too much. These dust clouds are where the stars and planets of the future will form. For all we know, the dust cloud that formed the solar system 5 billion years ago blocked somebody else's view in the galaxy.)

Fortunately, dust clouds do not affect all wavelengths of light equally—a small concession to astronomers. Dust particles in space scatter the blue light in a star's spectrum more severely than they scatter red light. (Similarly, Earth's atmosphere steals blue light from the sun's spectrum, producing the familiar color of our daytime sky.) Any star appears redder when viewed through a dust cloud, and stars that are naturally blue (the hot ones) lose much more of their color than the cooler, red stars do. The most luminous stars in the bulge are red giants which in fact emit more infrared than visible light. Armed with this information the best way to see through our galactic dust screen is to use infrared-sensitive telescopes. Another small concession to astronomers is the several lines of sight metaphorically known as "windows," that happen to have far fewer dust clouds These windows are valuable to people who wish to study the bulge in visible light rather than in infrared.

What does the bulge look like? If it were symmetrical, then on average, the observed properties of the stars (such as brightness, speed, and composition) on its left side would correspond with those on its right. But in 1991, Leo Blitz, of the University of Maryland, and David Spergel, of Princeton University, analyzed some eight-year-old infrared data that mapped the accumulated light of red giant stars in the galactic bulge. They found the left side of the galaxy was brighter than the right side, an observation that led to the first reliable description of the shape of the bulge. Assuming the bulge contains a constant mixture of stars, they interpreted the asymmetrical light as a slightly flattened, football-shaped bar of stars angled thirty-five degrees to our line of sight, with its near end to the left of the galactic center and its far end projecting beyond the center, and to the right. In other words, the galactic bulge was not round (like the yolk of our fried egg); it was elongated.

When this discovery was first announced, the newspaper *USA Today* reported on the front page of their sports section: "Milky Way galaxy—home to the sun and earth and superbowl—has a football-shaped core, rather than the sphere many astronomers have long believed, a new study says."

In most scientific enterprises, however, a single experiment or observation is not considered a discovery until it has been independently duplicated by others. And this is precisely what happened: a relatively rapid sequence of research papers confirming the findings of Blitz and Spergel appeared between 1991 and 1994. At least six different research groups, each using selected types of luminous red giant stars (with well-defined properties and minimal susceptibility to obscuring dust), found that the average brightness of many such stars on the left side of the bulge was slightly greater than a similar sample drawn from the right. After subtracting the effect of dust, each research group mod-

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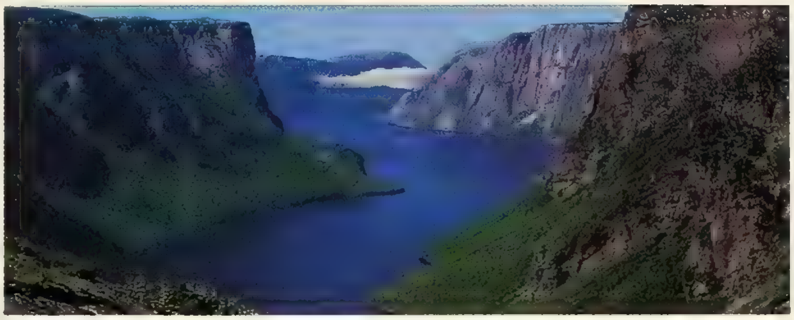

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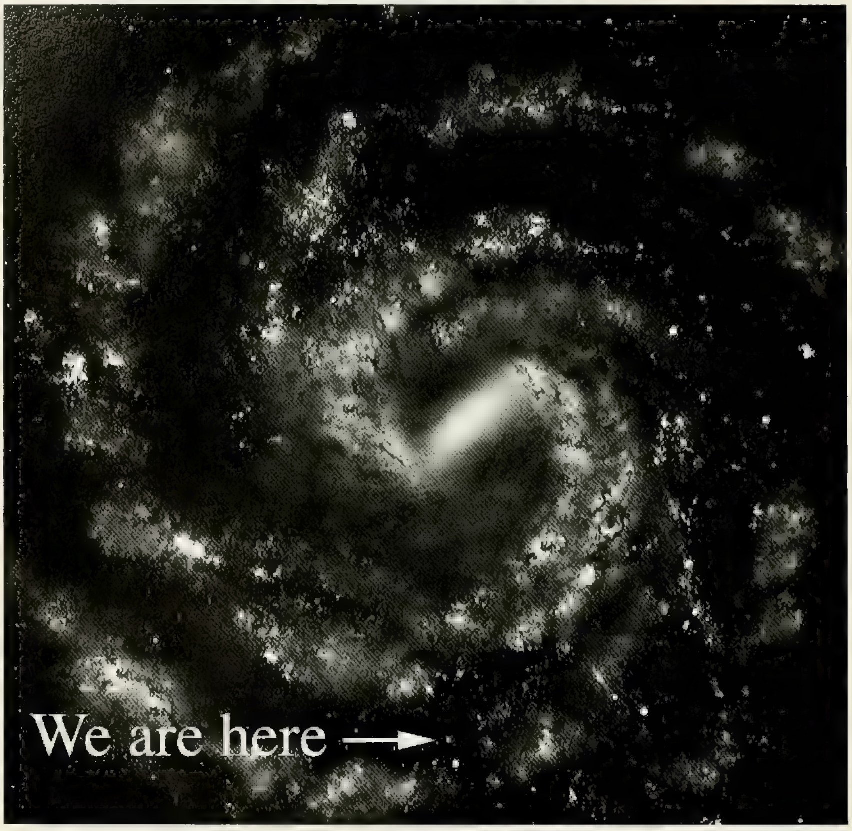
eled the light profiles and derived a similarly shaped bar at similar angles to the line of sight.

The only remaining doubt about the shape of the bulge centered on the possibility that galactic dust may possess properties that differ across the galaxy, and could thus make a symmetrical bulge masquerade as a football. If so, the studies that were more sensitive to the presence of dust, such as those that used visible light, should have revealed an anomalously prominent bar, perhaps something as elongated as a hot dog. But they didn't. And regardless of methods of analysis and star varieties chosen as tracers, there was good agreement among all researchers about the elongated shape of the bulge. Such is the profile of a genuine discovery.



After: Between 1991 and 1994, a consensus emerged among astrophysicists that the galaxy's center is bar shaped.

Was all this effort necessary? Possibly not. During a recent visit to the local candy store, I noticed that Mars, Inc., makers of Milky Way, may have known something about the structure of our galaxy before any of us did, because the full name of the candy as it appears on the wrapper is "Milky Way BAR."

Apart from being a curious factoid about the Milky Way, the existence of a bulge that is shaped like a bar has interesting consequences for a galaxy. In a flattened galactic disk, star orbits are confined to the plane. In a spherical bulge, stars orbit at all angles as they trace out the bulge volume. Some of these orbits are circular; others are elongated. But stellar orbits contained within a bar-shaped bulge are downright exotic. Common orbit shapes include figure eights, double- and triple-twisted loops, and bananas. And in spiral galaxies with bar-shaped bulges, the gas-rich spiral arms terminate on or near the ends of the bar, rather than circle inward to the center. The bar's tube-shaped gravity field serves as a cosmic conduit that allows colliding gas clouds from the spiral arms to plunge to the center of the galaxy and feed active bursts of star formation there. In some galaxies, the plunging clouds may be the food supply for a hungry, supermassive black hole.

The flood of high-quality data from observations of stars near the galactic center is relatively recent. But astrophysicists have a somewhat longer history of using radio telescopes to observe radio waves emitted by gaseous hydrogen. With their long wavelengths, radio waves travel through interstellar dust with ease. And as early as 1960, astrophysicists knew that the observed gas motions did not conform to what you would expect in a symmetrical bulge. But they also knew that you cannot always trust where gas has been or where it is going, especially near the galactic center where it is susceptible to all sorts of dynamic influences that normally go unnoticed by stars. For example, clouds of gas can be accelerated or disrupted by bursts of star formation, or they can collide and stick together like hot marshmallows, forcing them into a different orbit. The uncertainty was strong enough to thwart a consensus about the bulge's shape for decades. With hindsight, however, the velocities measured from the radio waves fit the appropriate noncircular orbits of a bar model very well.

In 1975, Ben Zuckerman, then of the University of Maryland, and his collaborators found ethyl alcohol (CH_3CH_2OH) in a dense cloud of molecules near the galactic center. Plenty of other molecules were already known to exist in the galaxy, but the alcohol received extra attention in the press. If you are curious, the estimated number of alcohol molecules relative to water molecules in the bulge would make a libation that is about 0.001 proof—we should not worry about drunk bulge aliens. But if you were to build a cosmic distillery to recover pure alcohol from the clouds, then there would be enough in the galactic bulge to fill approximately 100 octillion (10^{28}) liters of 200 proof. There is no avoiding it: Our Milky Way contains a fairly well stocked galactic bar.

In their 1994 and 1995 editions, the leading introductory astrophysics textbooks began to speak of the Milky Way bar as though it had always been an accepted feature of the galaxy. Some textbooks—and this essay—even have artists' renditions of what the bar probably looks like from a bird's-eye view. Our paradigm shift is thus complete. It was swift and mostly painless mainly because, by looking out of ou galactic womb (in directions above and below the galactic disk), we already knew that barred spirals existed and that they were common elsewhere in the universe. The discovery that the Milky Way is among them did not tear apart the world of physics at its seams, but it provided a closer approximation of the truths of the universe.

Neil de Grasse Tyson is an astrophysicis with a joint appointment at the America Museum-Hayden Planetarium an Princeton University.

August Trio

by Joe Rao

The Perseid meteor shower is usually the highlight of the August sky, but not this year. Because the full moon falls on the 10th, the night before the shower peaks, the sky will be flooded with moonlight, drowning out all but the brightest meteors. Nevertheless, August evenings are great for observing the summer triangle, the most prominent star pattern of the season. Rising high in the eastern sky, the three bright stars that form the grouping have long been used as a navigator's landmark. The points of the triangle are the brightest stars of three constellations: Vega in Lyra, Altair in Aquila, and Deneb in Cygnus. Famous as it is, the summer triangle lacks the official status of a constellation. Called asterisms, such informal groupings of stars are quite common. The "teapot," an easily recognized asterism in the constellation Sagittarius, is currently visible near the southern horizon.

In our northern skies, Vega appears to dominate the heavens from its position near the zenith during the evening hours in August. Because of its sharp, blue-white glitter, writers have often called it the "arc light of the sky." Deneb, its whitish glow visible toward the east, looks about one-third as bright. Altair, shining with a yellowish white hue, is located farthest south of the three and falls about midway between Vega and Deneb in relative brightness.

While to a casual stargazer Vega far outshines its two neighbors, astronomers have gained a different perspective on its brightness over the years. To be sure, Vega is about three times the size of our sun and about fifty-eight times as luminous, but its distance from us (about twenty-seven light-years) dims it considerably to our eyes. Altair, on the other hand, is an average star (only about half again the diameter of our sun and about nine times more luminous) but at a distance of only sixteen light-years, it is one of our nearer neighbors among the brighter stars.

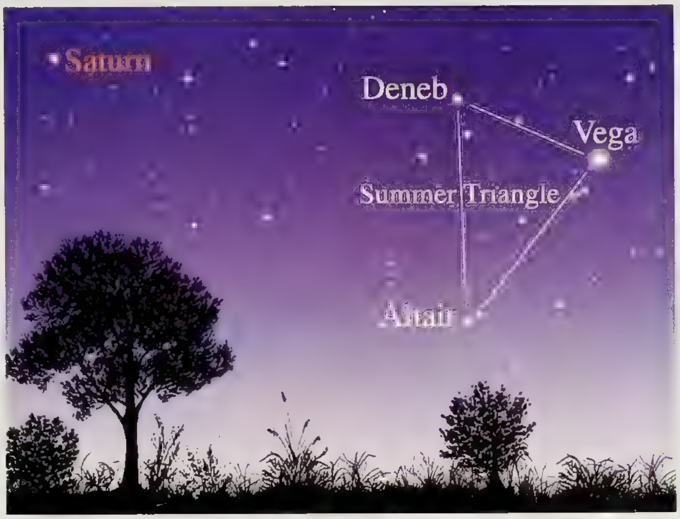
The third star, Deneb, is one of the most distant of what we call the nearer stars; the light we see started its journey to Earth roughly 1,600 years ago. To shine as brightly as it does in our sky, Deneb must be some 60,000 times more luminous than the sun. One of the largest supergiant stars known, it is twenty-five times more massive than our star, with a diameter some sixty times as great. Despite all these impressive statistics, we see it only as a fairly conspicuous, but by no means particularly notable, star.

The three stars of the summer triangle demonstrate that a star's "apparent magnitude" depends on its luminosity and its distance. If all stars were located at exactly the same distance, then their apparent magnitudes would be true indicators of their luminosities. When astronomers refer to the "absolute magnitude" of a star, they compare stars as they would be at a somewhat arbitrary distance of 32.6 light-years from Earth. If, for instance, our sun were removed to this distance, it would shine at an apparent magnitude of +4.8, a rather faint apparition to the naked eye.

If the three stars of the summer triangle were to be placed 32.6 light-years away, brilliant Vega would appear at magnitude +0.6, or just over a half magnitude fainter than it actually appears to us. Altair would rank as a second-magnitude star, appearing at +2.3. By far the greatest change would occur with Deneb. It would appear to glow at magnitude –7.2: more than ten times brighter than Venus and bright enough to be readily evident even through the brilliance of our daytime skies.

The Planets in August

Mercury might be spied in the evening sky during the latter half of August, especially from the southern states. Look for it very low in the west at midtwilight. Binoculars will probably be needed to see it from the northern states. A skinny crescent moon will hover about four degrees below and slightly to the right of Mercury on the evening of the 27th.



Saturn and the summer triangle are high in the southeastern sky.
Dennis Davidson

Venus ventures behind the sun this month and reaches superior conjunction on August 20 as it enters the evening sky.

Mars, in Virgo, sets less than two and a half hours after sundown in August and fades from magnitude 1.3 to 1.4 during the month. It will pass within two degrees to the north of the first-magnitude, bluish star Spica on the 28th. The crescent moon pays Mars a visit twice this month, on the evening of the 1st and again on the 29th.

Jupiter is the most prominent "evening star," shining at magnitude –2.3 through most of the month. At dusk it is in the south–southwest, near the head of Scorpius and to the upper right of its ruddy star Antares; it sets near midnight. Jupiter is below and to the right of the moon on the 5th.

Saturn, approaching opposition in Aquarius, rises out of the southeast about 10:30 P.M., local daylight time, on the 1st, but two and a half hours earlier by the 31st. It will stand about five degrees directly below the rising gibbous moon late on the evening of the 12th. On the 10th, when Earth lies in the plane of Saturn's rings, the planet will appear ringless for the second time this year. It will appear to brighten slightly, to magnitude 0.8 by month's end, because after the 10th, we'll begin to get a very narrow view of the sunlit south side of the rings, reflecting a thin line of light toward us.

The **Moon** is at first-quarter phase on the 3d at 11:16 P.M., EDT; full on the 10th at 2:15 P.M., EDT; last quarter is on the 17th at 11:04 P.M., EDT; and new moon is on the 25th at 12:31 P.M., EDT.

Meteorologist Joe Rao is a lecturer at the American Museum-Hayden Planetarium.

Clover Lick Barrens, Indiana

by Robert H. Mohlenbrock

Bordering Kentucky, the southern portion of Indiana's Hoosier National Forest consists of rugged, rocky, hilly terrain with picturesque streams that eventually empty into the Ohio River. An upland forest dominated by white oak, tulip poplar, black gum, and red maple covers the ridges. Sourwood, a medium-size tree common in the Appalachian Mountains, is found here and there, while smaller trees and shrubs include ironwood, flowering dogwood, redbud, winged elm, sassafras, sumac, and red cedar. Bittersweet with its yellow fruits, prickly stemmed greenbriers, and other vines climb the trees, and wildflowers occasionally color the forest floor—phloxes, partridge pea, goldenrod, winged crownbeard, Joe-Pye weed, and shining aster.

While surveying this forest in the spring of 1987, botanist Mike Homoya and biologist Jim Aldrich, both with the Department of Natural Resources, noticed a number of prairie plants, a good indication that in earlier times, the area may have been more open. The prairie plants were growing beneath stunted oaks on very rocky soil near the edge of a ridge, about a fifty-foot drop-off above Clover Lick Creek. When Homoya checked the original surveyor's notes for the region, he discovered that on September 25, 1805, the surveyor recorded "a mile of poor barrens and grassy hills, with much flint and a few shrub oaks."

Flint, known as Derby chert, was still scattered over the terrain, but the grassy hills with just a few shrub oaks had apparently given way to a dense growth of stunted, gnarly oaks with a sparse understory of prairie grasses and prairie wildflowers. This conversion from barrens—forest openings with prairie plants and stunted trees—to stunted forest probably came about because fires had been suppressed, particularly after the Hoosier National Forest gained control of the area. Without periodic fires, the oaks became plentiful, providing too much shade for the good growth of prairie species.

Until a few years ago, as the government added worn-out farmland to Hoosier National Forest, open areas were replanted with nonnative pines. Recently, however, efforts have increased to restore some of the habitats present during presettlement times. In 1993, forest personnel decided to bring back the former barrens

Prairie species, above, sprout in a clearing following a second burning of the barrens in spring 1995. Left: Woody plants cloak a sandstone ridge.

All photographs by Adam Jones; Dembinsky Photo Associates

Yellow star grass blooms near a charred log.

above Clover Lick Creek. Botanist Steve Olson assisted in planning a spring burn of the barrens and adjacent old fields, to suppress the growth of woody plants while encouraging barrens-type species. Olson kept a detailed diary of how the prescribed burn affected members of the community, including animals as well as plants. Following the 2,200-acre burn, which was set Tuesday, April 6, and took three days, Olson observed:

"Before the fire, tiny seed ticks were plentiful as one walked through the area. On the first weekend after the fire, no ticks were found! Other invertebrates, including moths and butterflies such as mourning cloaks and blues, were everywhere. . . . As for vertebrates, frogs and toads seem oblivious to the burn. They were calling all over the place this weekend. Fence lizards and skinks were running around and climbing trees. I noted three casualties over the entire burned area—two box turtles and one earth snake, which got caught in the open. . . .

"[April 26] The most striking thing I noticed was the distribution of birds. I saw or heard very few species until I was at the fireline. Then everything seemed to be there: spring migrants, summer residents, and permanent residents; forest interior species, edge species, and open-land species. Moles seemed to be rather active. Their runways crossed the old roadways and parts of the fireline frequently. Flies were in the air, and moths, skippers, and butterflies were active. . . . The barrens had burned, leaving small grassy refugia. Small encroaching shrubs and trees were top-killed. . . . Wildflowers, grasses, and other green things are coming up all over the place. . . .

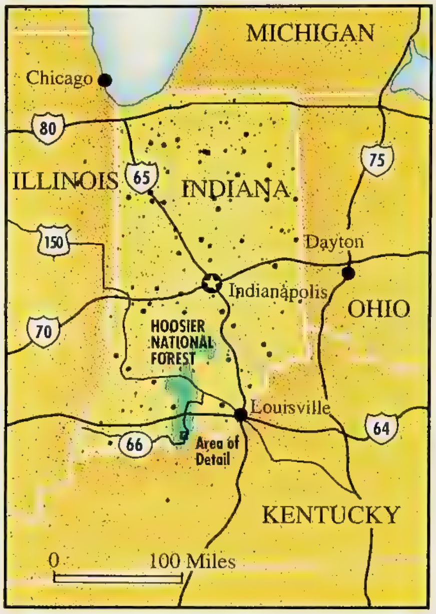
"[June 28] I spent an entire humid morning wandering through neck-deep grasses and found only one tick and no chiggers. Other more innocuous invertebrates of note include countless grasshoppers and a wide diversity of butterflies and dragonflies. I noticed annual cicadas singing as well. In all cases these invertebrates were most conspicuous in the burned parts of the area. Deer are . . . busy munching. Rabbits are also rather abundant. . . . There are hundreds of plants blooming in the open areas and even some in the burned forest. . . ."

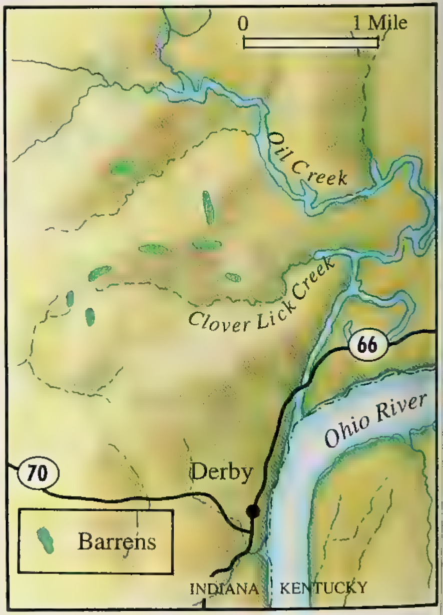
The following year, in mid-September, Homoya and Olson introduced me to the area, which they have named the Clover Lick Barrens. Big bluestem, little bluestem, and Indian grass, all grasses that once extended across the vast prairies of central Illinois and Missouri and into Kansas, grew abundantly within a sparse woody cover of post oak, blackjack oak, and rusty nannyberry. Scattered about was an array of prairie wildflowers—hoary puccoon, yellow gentian, purple coneflower, rosinweed, blazing star, tickseed sunflower, rattlesnake-master, flowering spurge, narrow-leaved aster, and false boneset. Small pieces of limestone, calcareous shale, and flint littered the soil.

As we walked away from the barrens' edge above the stream, we crossed over an abandoned dirt roadway and into a forest of rock chestnut oak. Instead of calcareous shale and limestone, chunks of sandstone were scattered about, a type of rock that weathers to form acidic soil. The plants of this woods were acid-loving, and completely different from the barrens' plants. Conspicuous among them was lowbush blueberry, which produces tasty fruit during the summer.

The old dirt roadway, which happens to serve as a boundary between the barrens and the sandstone-littered forest, provides a drainage corridor after heavy rains. Its vegetation consists of moisture-loving plants, among them dark green bulrush, inland sea oats, grass-leaved goldenrod, and mistflower.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the U. S. national forests and other parklands.





Clover Lick Barrens

For visitor information write:
Supervisor
Hoosier National Forest
811 Constitution Avenue
Bedford, Indiana 47421
(812) 275-5987

"You Are in the 'Holy Ground' "

Finding *Tyrannosaurus rex*

he Museum's new Hall of
aurischian Dinosaurs and the
all of Ornithischian Dinosaurs
pened in June, part of a larger
enovation of the Museum's fos-
l halls that will be completed
1996. Many of the original
ounts, like that of Tyran-
osaurus rex, *have been con-*
erved, newly cleaned, and re-
ssembled to reflect recent
cientific perspectives on di-
osaur evolution.

Carnivorous dinosaur remains
re especially rare, making up a
nall percentage of all the dino-
aurs found. The remains of
nly about a dozen tyrannosaurs
ave been discovered, and most
re mere fragments. In 1902 and
908, paleontologist Barnum
rown, the Museum's most suc-
essful dinosaur collector, found
vo spectacular exceptions in
e Hell Creek Formation of the
lissouri Breaks in east-central
lontana. Brown had received a
port from zoologist W. T. Hor-
aday that the area was full of
rge dinosaur fossils, which he
ad photographed while hunting
the area. Brown went to in-
estigate the site, 130 miles
om the nearest railhead, in July
902. Henry Fairfield Osborn, at
at time head of the Museum's
ewly organized Vertebrate Pa-
ontology Department, and
ter the Museum's president,
rote encouragingly that "judg-
g by your reports, you are in
hat Marsh [O. C. Marsh, Yale
niversity's premier paleontolo-
ist] used to call the 'Holy
round'; and there is every reason to think . . . you may find something of real value."

Brown searched for more than a month, without much luck, and was nearly ready to give up when he decided to try one more day. The human imagination is richer as a result: "Quarry No. 1 contains the femur, pubes, part of the humerus, three vertebrae, and two indeterminate bones of a large carnivorous dinosaur, not described by Marsh," Brown wrote to Osborn in August. "I have never seen anything like it from the Cretaceous." Three years later, when Osborn published Brown's findings, it was the first time a tyrannosaur had been scientifically described.

The pelvis and limbs of the Museum's original 1915 mount of an upright T. rex *stood over twelve feet tall.*

AMNH

Six years later, Brown found the other specimen buried deep in the ground at Hell Creek. Brown removed it with the only tools he had: pickaxes, brushes, and dynamite. It was not as well preserved as the first find, with one exciting exception—it was the finest skull of a carnivorous dinosaur ever found, providing a wealth of information on how dinosaurs hunted and consumed their prey.

In the late Cretaceous, Hell Creek lay on the edge of what was once a vast inland sea that stretched from Canada to Mexico. The site provided the Museum with samples from both ends of the fossil spectrum—the familiar as well as the extraordinary. For example, remains of *Triceratops* were abundant. Brown estimated that, over seven years, he found parts of at least 500 skulls and countless other bones. The diversity of dinosaur remains found there indicates that the region was a Cretaceous Eden. Unfortunately, part of this site now lies under the waters of a reservoir.

The American Museum of Natural History is located on Central Park West at 79th Street in New York City. For more information regarding the Museum's hours and admission fees, call (212) 769-5100.

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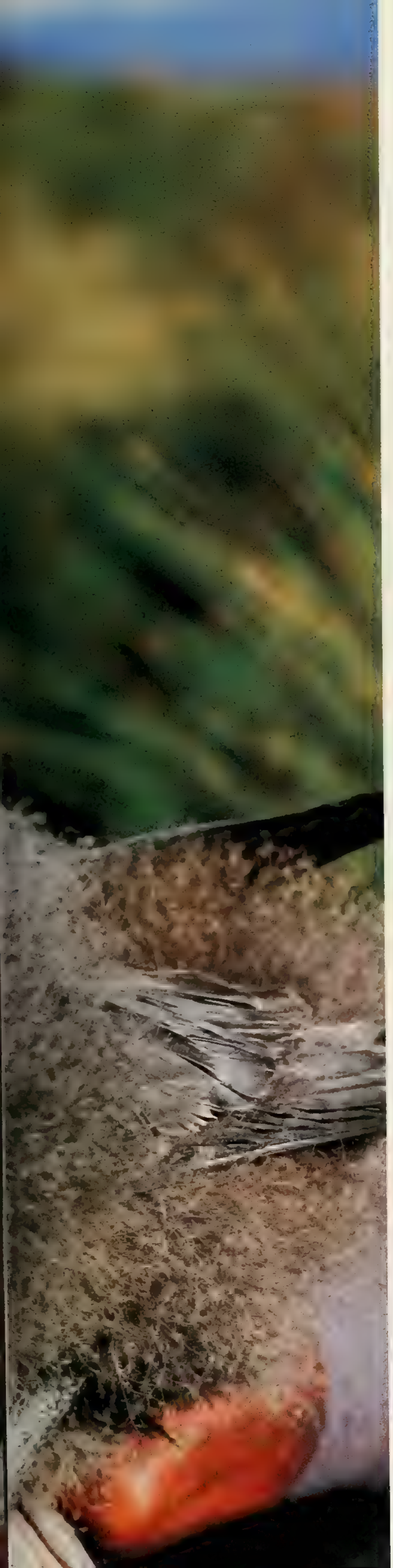
story: 125 Years of Expedition and Dis-
very, *by Lyle Rexer and Rachel Klein;*
reword by E. O. Wilson. To be published
Harry N. Abrams, Inc., in November.



A short-tailed shearwater chick, left, sits tamely in a catcher's hand.

A Muttonbird in the Hand

Tasmania's Aborigines harvest a bountiful and sustainable resource

Text by Irynej Skira

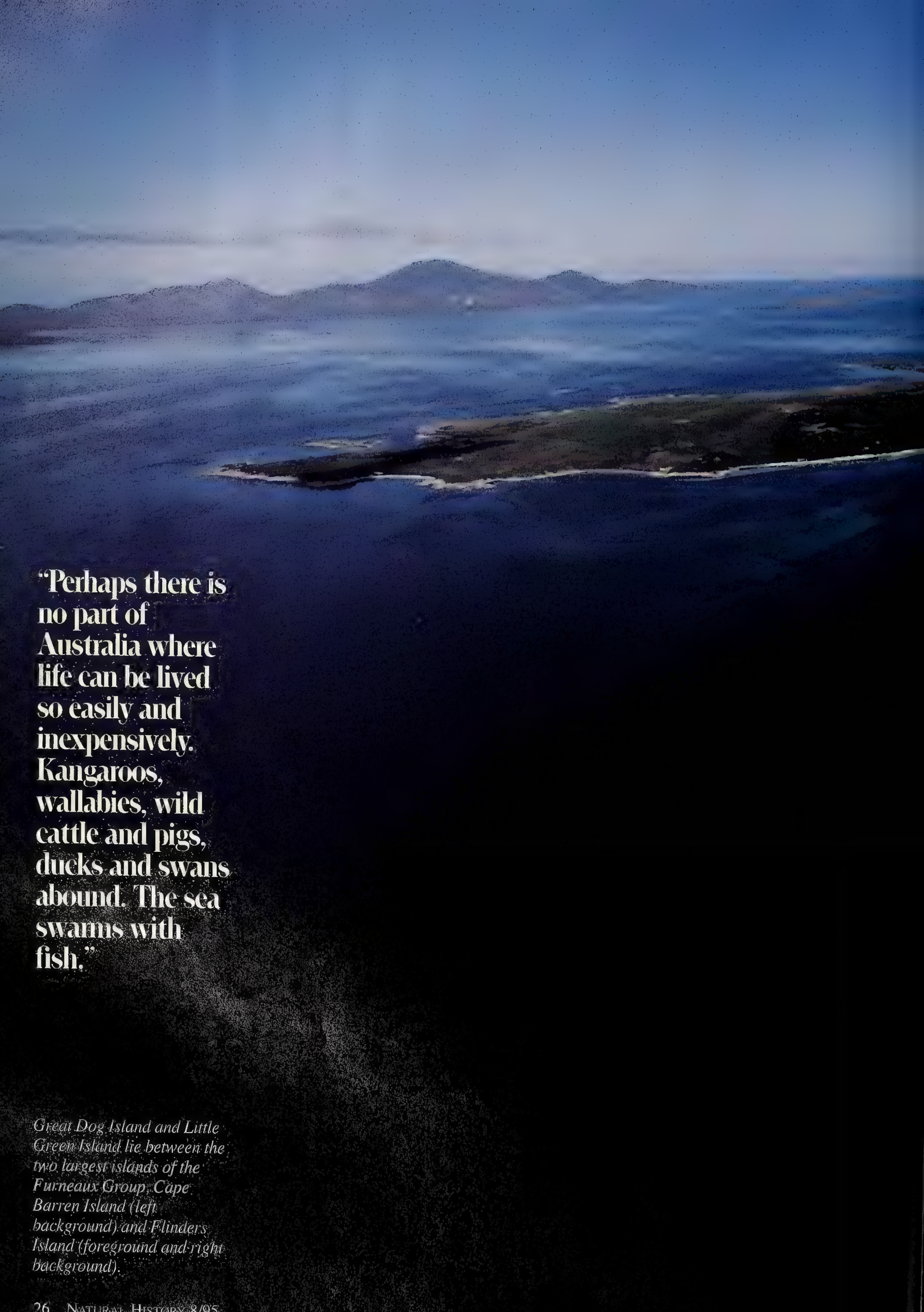
Photographs by Esther Beaton Terra Australis Photo Agency

Muttonbirding is hard, hot, dirty work. Out by sunrise, the "catchers" systematically work their way through the birds' breeding colonies in search of the fat chicks. Reaching into the arm's-length burrows that the parent birds have dug under the tussock grass near the beach, they extract a chick. If it is obviously too light, they put it back; otherwise, they snap its neck with a quick flick of the wrist, killing it instantly. Each year, from March 27 to April 30, muttonbirders kill thousands of short-tailed shearwaters, or muttonbirds, on some of the grass-covered, granite islands of the Bass Strait between Tasmania and the Australian mainland. The species is one of several seabirds whose fatty flesh reminded early British colonists of mutton. The birds are brought to a processing shed within a half hour of being caught, as they are easier to pluck while still warm. The catchers squeeze out the bird's stomach contents for its oil (used as an additive in medicines and foods); then workers known as shed hands pluck, gut, trim, and pack the carcasses, usually for freezing.

The chicks are a logical target for harvesting not only because they are easier to catch but also because they are plumper than the adults. An adult, which has a wingspan of thirty-seven inches, weighs about twenty-one ounces; a chick, fattened to survive its period of adjustment to independent living, weighs twenty-eight to forty-two ounces. And because at least half the chicks will die before they breed, a fair proportion of the harvest will not affect the breeding population, whereas the taking of adults would have a pronounced effect.

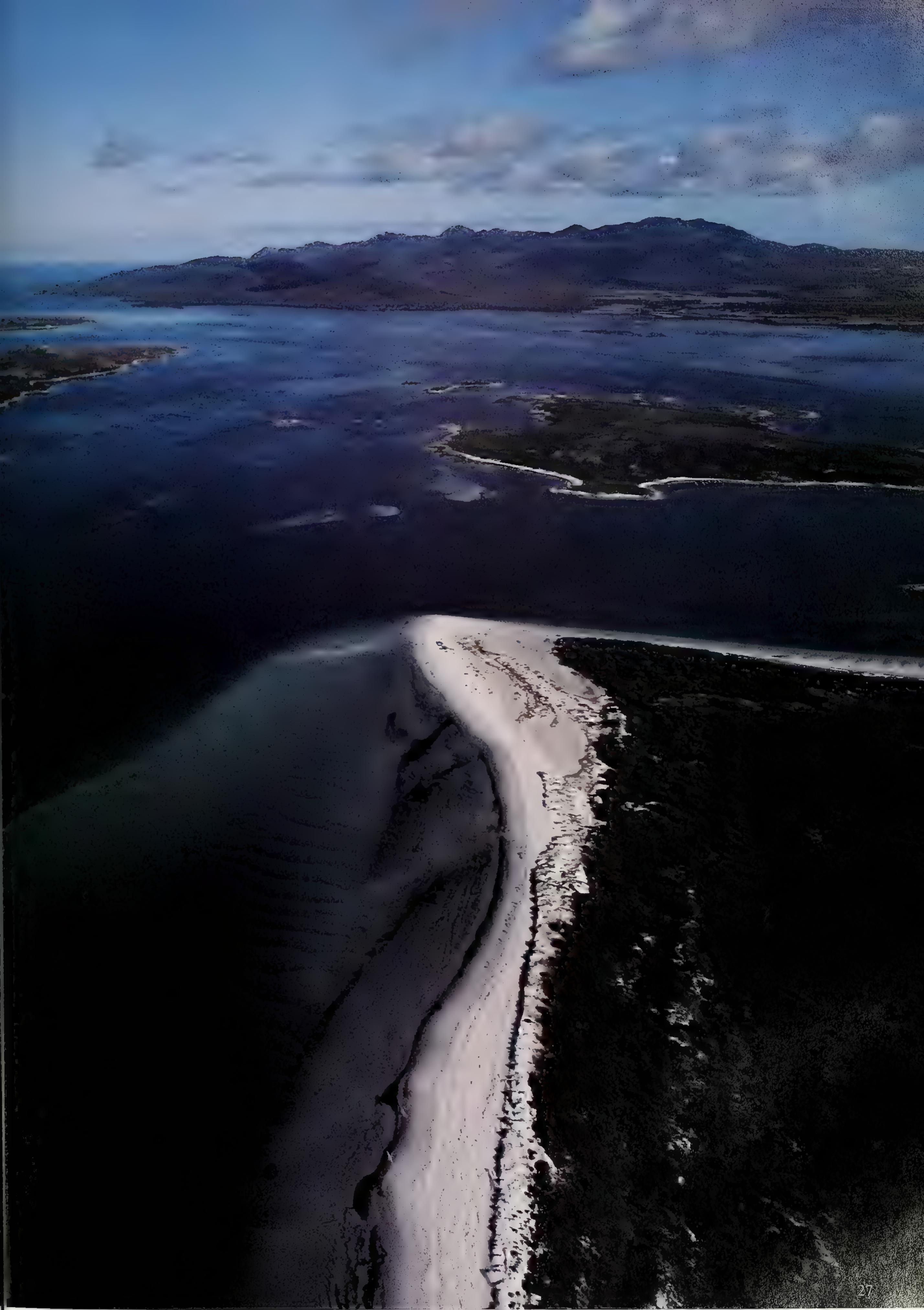
The chicks are harvested not only because they are easier to catch but also because they are plumper than the adults.

Although Tasmania has been inhabited for 35,000 years (see page 32), this intense harvesting of muttonbirds appears to have originated in historic times within a small, mixed group of Europeans and Aborigines. In 1788, when Europeans founded the colony of New South Wales (Sydney), their first settlement in Australia, Tasmania was inhabited by about 4,000 Aborigines. These hunter-gatherers ate shellfish, seals, birds, and such land mammals as wallabies. They had



> “Perhaps there is no part of Australia where life can be lived so easily and inexpensively. Kangaroos, wallabies, wild cattle and pigs, ducks and swans abound. The sea swarms with fish.”

Great Dog Island and Little Green Island lie between the two largest islands of the Furneaux Group, Cape Barren Island (left background) and Flinders Island (foreground and right background).



Tussock grass, above, helps protect the burrow of an adult bird. Opposite page: A muttonbird breeding ground on Flinders Island.

Muttonbirding began not long after the seal population in the Bass Strait had been depleted.

several names for the muttonbird (*yolla* seems to have been the most common), but the bird was not a preferred resource.

The earliest recorded European consumption of the bird dates from February 1797, when the *Sydney Cove,* a supply ship on its way to Sydney, beached in the Furneaux Group of islands off Tasmania. The crew landed safely on what became known as Preservation Island and erected tents near muttonbird burrows. The birds, plus a daily allowance of a cupful of rice, constituted a great part of the crewmen's diet until they were rescued five months later. But the opportunity to collect muttonbirds in quantity did not initially draw the attention of Europeans any more than it had been a focus for the Aborigines.

The colonists were more excited by the rich sealing grounds around Cape Barren Island, also in the Furneaux Group, which they learned about in 1797. In a very few years, large sealing gangs slaughtered almost a quarter of a million fur seals in the Bass Strait. Soon the Sydney-based entrepreneurs no longer found it very profitable to exploit the seals. By the 1830s, only twelve sealers of European origin remained in the Bass Strait, principally on the islands between Flinders and Cape Barren islands. They took Aboriginal women as wives, including four from mainland Australia and one Maori from New Zealand, as well as nine from Tasmanian tribes (the unequal numbers of men and women reflect remarriages after some of the women died). The members of this nascent community were termed sealers, straitsmen, islanders, or Bass Strait islanders.

The modern tradition of muttonbirding arose soon after, as the islanders sought less arduous ways of making a living. At first, the main product consisted of feathers from adult birds for use as mattress fill. The islanders also collected eggs in November and December; fledglings in March and April for their meat, oil, and fat; and adult birds, which they salted or smoked.

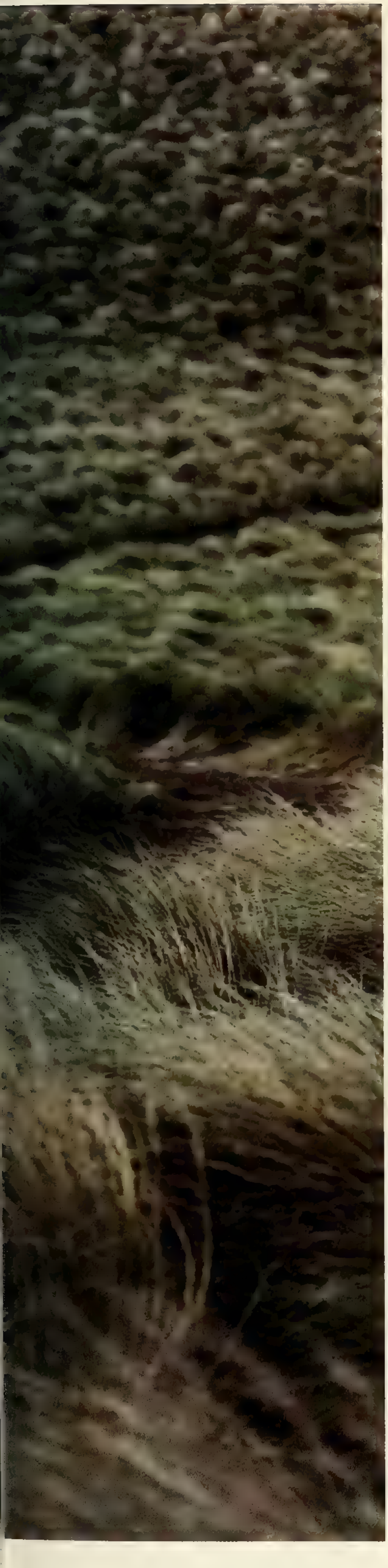
Beginning in the 1860s, other people settled near the islanders—Europeans who took up leases or bought land. By 1872, only 84 of the 227 inhabitants in the Furneaux Group belonged to the original islander community. About this time, most of the islanders were forced to move to Cape Barren Island. Fearing eventual displacement, they petitioned the government to reserve part of the island for them. In 1881, ten square miles were set aside on the island's western end. Administered by the State of Tasmania, the reserve did not provide economic independence for the islanders, but it did give them the security to establish homes.

The islanders lived in constant poverty; one was quoted in a newspaper article as saying that he had not had any sugar in his tea for more than a month or any money to buy any. But Henry Montgomery, the bishop of Tasmania in the 1890s (and father of Field Marshall Bernard Montgomery, of World War II fame), was so taken with the islanders' seemingly relaxed lifestyle that, despite the obvious poverty, he wrote in April 1891:

> Perhaps there is no part of Australia where life can be lived so easily and inexpensively. Kangaroos, wallabies, wild cattle and pigs, ducks and swans abound. The sea swarms with fish. . . . [This is] a region where, in one sense, it is "always afternoon."

As the human population grew, the harvesting of muttonbirds and the clearing and burning of land for farming and grazing obliterated several of the bird colonies. At the end of the nineteenth century, about a half million adults and chicks were being taken each year. Regulations to protect adult birds, eggs, and habitat were put in place in 1891; later, rules were established to improve hygiene in the industry. Muttonbirding reached its peak in the first two decades of the twentieth century, when as many as a million chicks would be taken in a single year; now about 200,000 are taken.

Anyone may obtain a short seasonal license to collect a limited number of muttonbirds for food, but a commercial licensee must own a lease for a bird colony and its "processing shed," where the



birds are cleaned. In the past few years there have been fourteen to sixteen licensed operators, or shed bosses, both males and females, who together employ about forty catchers (invariably men) and a similar number of shed hands.

Today an estimated 23 million muttonbirds breed on offshore islands and mainland headlands in southeastern Australia, the biggest colonies being located in the Furneaux Group. A few decades ago no one could say whether the population could withstand the toll of hundreds of thousands killed annually. In 1947, the late Australian ornithologist Dominic Serventy began bird population studies to help resolve this question. I saw my first muttonbird twenty years ago, when I joined the Tasmania Parks and Wildlife Service and was asked to assist Serventy. Within two years the project was entrusted to me, and ever since I have found the fieldwork a marvelous break from my office duties.

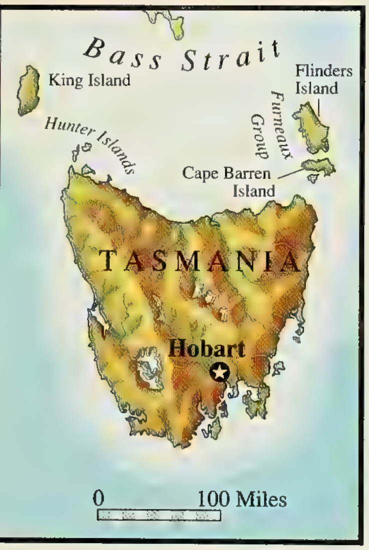
The long-term studies show that the birds follow a very predictable life cycle. The breeding pairs return in late September from their annual migration to the North Pacific. They refurbish their burrows, and the females each lay one egg. All the eggs are laid within a two-week period,

Muttonbirding reached its peak in the first two decades of this century, when as many as a million chicks would be taken in a single year.

Terry Butler, left, carries a load of about seventy chicks to a processing shed. Don Willis, below, a non-Aborigine, looks for occupied burrows on Great Dog Island.

Joe LeMonnier

PACIFIC OCEAN
PHILIPPINES
BORNEO
NEW GUINEA
SUMATRA
JAVA
INDIAN OCEAN
AUSTRALIA
Sydney
Melbourne
Area of Detail



85 percent between November 23 and November 29. The mates take turns incubating the egg for shifts of ten to sixteen days, and after about fifty-three days, the chick hatches, sometime between January 10 and 23. For the next ten weeks the chick remains in the burrow and is fed by its parents, which make countless forays during the day to dive beneath the waves for fish, squid, and krill. Usually only 60 percent of the parents are successful in fledging a chick (most losses occur at egg laying or hatching).

The chicks get their final feeding in early April. Two weeks later, no doubt hungry, they emerge from the burrows in the evening and make their first attempts to fly (they are usually too heavy to succeed right away). During the night they wander and at dawn enter a burrow for shelter from predators. This "travel" phase is recognized by muttonbirders, who may comb the same area up to three times during March and April to hunt the chicks.

As part of my research, twice each year I revisit a small island with a colony that is protected from harvesting. In December, I spend three weeks feeling inside the nesting chambers at the ends of the burrows. I record the burrow number, the band number of the bird, and the presence or absence of an egg. Normally a muttonbird burrow is only the length of an arm, but as a result of my snooping, many of the birds have extended their burrows up to six feet. I get around this by breaking a fist-size hole from the surface, which I then cover with a rock. I return again in March to band the chicks.

This research has provided a detailed picture of muttonbird reproduction and mortality. In December 1990, for example, I found the remains of bird 50650/40095 in her burrow beneath the tussock grass. She had first been banded in November 1957, when she was a parent incubating an egg. She was missed the following year, but was subsequently found in the same burrow

The Fall and Rise of the Tasmani

by Richard Cosgrove

A few decades ago, anyone looking for a Tasmanian Aborigine would have been told that—tragically—all of them died out in the nineteenth century. But almost unnoticed, a small community of mixed European and Aboriginal descent has survived in the islands of the Bass Strait between Tasmania and Australia. For a long time, what held them together was the annual harvest of muttonbirds. More recently, they and their relatives throughout Tasmania have laid claim to their Aboriginal roots. It is a heritage that stretches back thousands of years.

Traveling across transitory land bridges, *Homo erectus* reached Java from mainland Southeast Asia at least a million years ago. But this human ancestor did not cross the sixty miles of open sea that separated Indonesia from the continental shelf of Australia. Not until anatomically modern humans—evidently equipped with boats—arrived on the scene did people make the trip. Exactly when this occurred is debatable, but it may have been as early as 53,000 years ago. By 35,000 years ago, humans had spread throughout New Guinea, Australia, and Tasmania, which were often connected by land bridges.

One of the oldest archeological sites in Tasmania is Parmerpar Meethaner, in the northwest, a quartzite rock-shelter that was occupied repeatedly from 34,000 to about 200 years ago. But much more physical evidence of the earliest Tasmanian inhabitants has come from limestone caves in the southwest, dated to between 30,000 and 13,000 years ago, the period of the last great ice age. These rich deposits include thousands of smashed bones from the red-necked wallaby, the inhabitants' principal prey. Animal remains also include wombats, platypuses, possums, and emus, but not any of the so-called giant marsupials, which apparently were already extinct in this region by the time humans arrived.

Prehistoric Tasmanian artists left stenciled images of their hands deep within some of the caves. Their small stone tools, known as "thumbnail scrapers," may have been used for woodworking, while stout bone points and spatulas made from wallaby leg bones were perhaps intended for preparing hides. Pieces of Darwin glass, a melted quartz from a meteorite-impact crater on the Tasmanian west coast, show that the cave dwellers either traveled widely or engaged in trade with distant groups.

The caves were abandoned 13,000 to 11,000 years ago, as the climate became milder. Ice Age glaciers melted, sea levels rose, and Tasmania was cut off from the mainland. Beginning about 10,000 years ago, until the arrival of European explorers, Tasmanians apparently remained isolated from all other groups. We find no evidence of hafting, common on the Australian mainland since early times, or of stone axes, found in the southeast mainland by 5,000 years ago. A newer, "microlithic" stone-tool technology that appeared on the mainland between 4,000 and 3,000 years ago never spread to Tasmania. Neither did the dingo, a dog introduced from Southeast Asia into Australia about that time.

In the 1960s and 1970s, the islanders, once viewed as "half-castes," came to regard themselves as Aborigines.

every year until November 1988, the last time she was handled alive. During this period she had two mates and produced twenty-three chicks, of which eight have been recaptured. Allowing the average five years required for her to have reached sexual maturity, bird 50650/40095 must have been at least thirty-eight years old when she died, well above a muttonbird's recorded average life span of fifteen years.

Based on the population research, I calculate that a safe harvest level is 37 percent of the chicks present when the season opens in March. In actual practice, commercial muttonbirders take from 11 to 28 percent from four large colonies in the Furneaux Group and northwest Tasmania; other Tasmanian colonies are untouched, many officially closed to amateur and commercial muttonbirders alike as nature reserves. Elsewhere in Australia the birds are fully protected. Thus the harvest is far from posing a threat. In fact, as Serventy hypothesized, if mut-

Makeeta Long and Aaron Burgess, above, left, are children of Aborigines working on Trefoil Island, off the northwest tip of Tasmania. Vivian Beeton, above, is a descendant of Thomas Beeton and his Aboriginal wife, one of the couples that founded the islander community.

origine

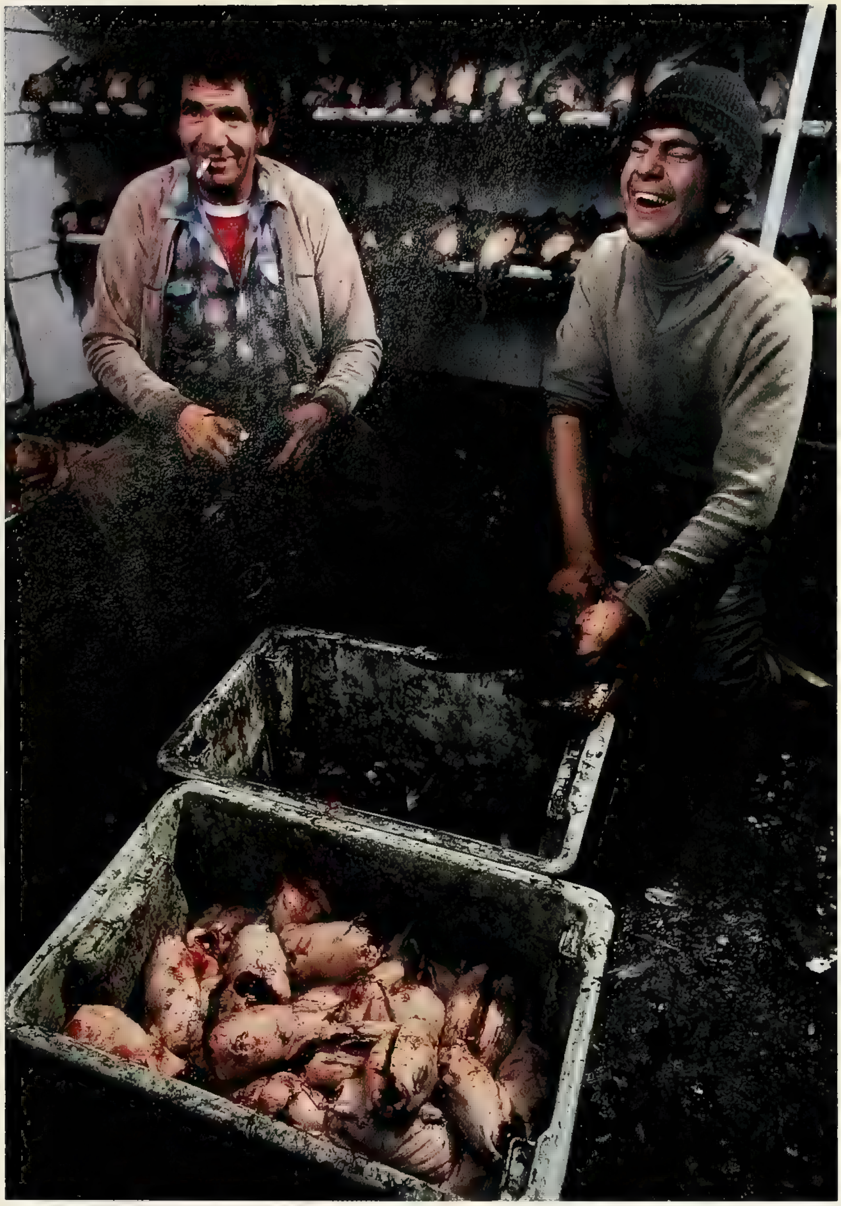
The testimony of eighteenth-century French, Dutch, and British explorers paints a picture of a simple, but efficient and effective technology. Tasmanians may have lacked spear-throwers and hafted implements, but they possessed long lances, throwing sticks, watercraft, reed baskets, water containers, and mortars and pestles. They lived off the abundant coastal resources—crayfish, abalone and other shellfish, birds and their eggs—as well as the inland kangaroo, wallaby, possum, waterfowl, and emu. Their vegetables included tubers and underground fungi. In the central highland and on the west coast, they made substantial shelters of wood and bark, decorated inside with drawings of animals, men, women, and symbolic designs. They incised their bodies with designs of circles, lines, and dashes. Early accounts describe dances and large gatherings, especially during the waterfowl egging season on the Tasmanian east coast.

Nineteenth-century historic sources suggest that the Tasmanian population, consisting of at least nine tribal groups, totaled about 3,000 to 5,000 people. This may be an underestimate, however. A population that small and that isolated would likely have diverged physically from other groups because of genetic drift, the accumulation of chance differences. But recent research has shown that the Tasmanian Aborigines resembled their mainland cousins. This suggests that the population may have been larger, on the order of tens of thousands.

After 1803, when Europeans established a penal colony on the south coast near Hobart, conflicts arose between the Aboriginal inhabitants and the new settlers. Open warfare became particularly intense in the fertile Midland Valley, where Aboriginal hunting lands were granted to European pastoralists engaged in the production of wool for English mills. In 1829, George Augustus Robinson was dispatched to round up the remaining Aborigines and move them to the settlement of Wybalenna on Flinders Island in Bass Strait. The policy at the time was to Christianize and "civilize" them. Some 120 people were resettled, but more than half died of disease and despair. In 1847, the forty-seven Aborigines who remained were transported back to the Tasmanian mainland to live in former convict barracks at Oyster Cove, near Hobart. Many died there of respiratory illnesses. The last "full-blooded" Tasmanian Aborigine, Truganini, died in 1876.

Meanwhile, a small number of European men and Aboriginal women created families in the islands of Bass Strait. Here a strong community survived, whose common heritage and tradition of muttonbirding have become the basis for an Aboriginal cultural revival. Today some 9,000 Aborigines trace descent from the ancestral islanders. They have struggled hard to gain recognition of their status, and they continue to fight for land rights and for control and custodianship of their cultural heritage.

Richard Cosgrove is a lecturer in the School of Archaeology, La Trobe University, Melbourne.



Royce Mansell (left) and Rohan Gregory gut muttonbirds in a processing shed. Opposite page: Don Willis plucks muttonbirds.

"Birding time still reminds you of the old days, of the old hands that were there before you and the ones that taught you."

tonbirders had not exploited the islands of Bass Strait, sheep and cattle farmers would probably have moved in, and the grazing animals would have destroyed the majority of the local muttonbird colonies.

More precarious has been the survival of the islander community. Many left Cape Barren Island following World War II to seek work on Flinders Island and in Tasmanian mainland towns. While the total resident population in the Furneaux Group is 900, only about 100 are descendants of the original islanders. But the tradition of muttonbirding has kept the community from disintegrating.

In the 1960s and 1970s, the islanders, once viewed as "half-castes," came to regard themselves as Aborigines in recognition of their ancestral tribal blood. The mixed nature of their genetic and cultural ancestry was of less importance to them than the direct link with the people who had inhabited Tasmania for thousands of years. After some hesitation, the government officially acknowledged their status alongside that of other Aboriginal groups in Australia. They are the only living remnant of the indigenous Tasmanian population, since the tribal Aborigines elsewhere in Tasmania were wiped out by a deliberate campaign of extermination and by introduced diseases against which they had no natural defense.

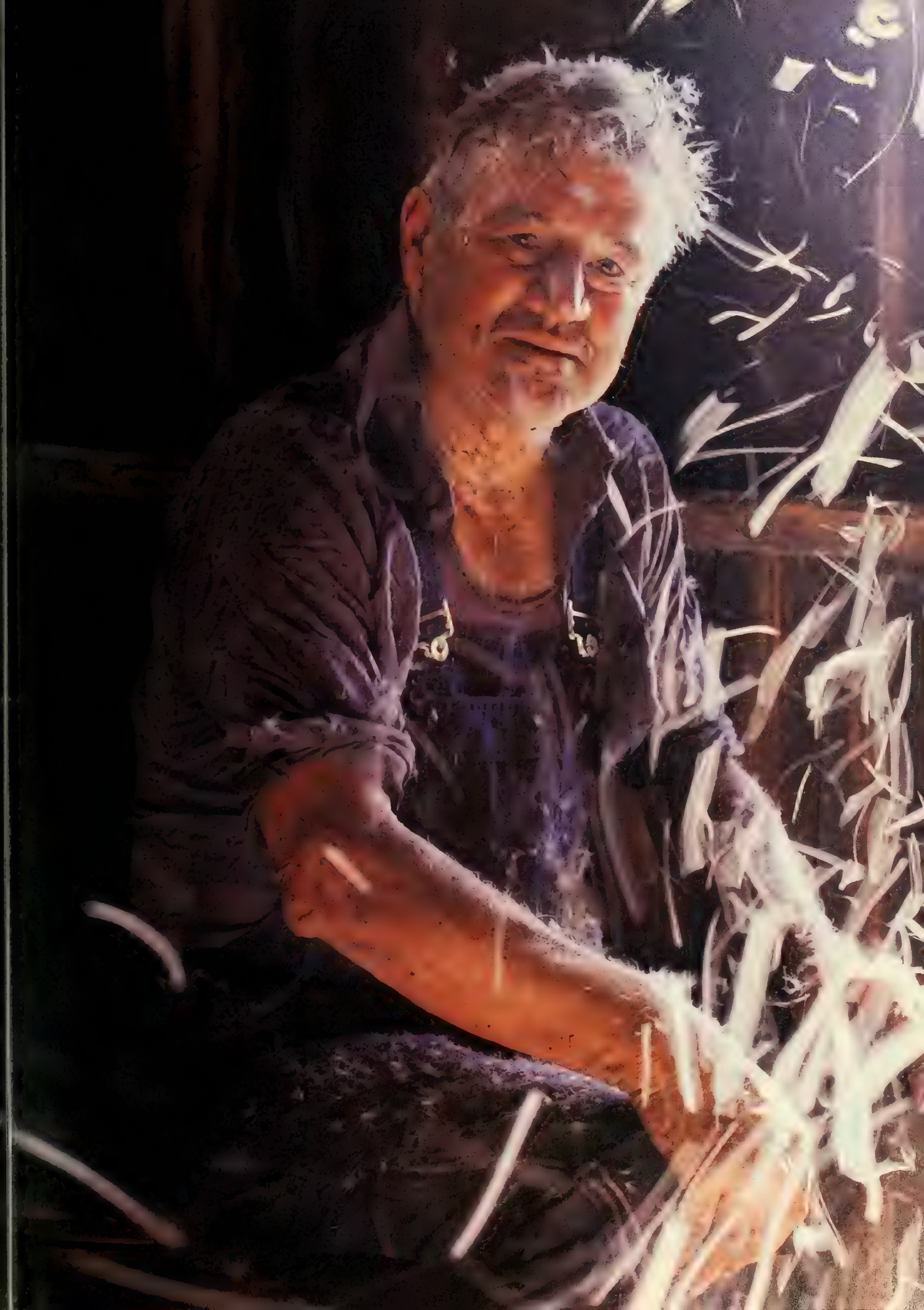
"What is the substance of Aboriginality?" I recently asked Steve Stanton, former chairman of the Tasmanian Land Council. He said, "Aboriginality is the feeling of belonging to the land, knowing that your ancestors were Aboriginal and that they walked that land" (the land includes not only specific sacred and heritage sites but also the total landscape). Or as Kim Stonehouse, one of the licensed muttonbirders, explained Aboriginality to me, "That's what's still in the blood I suppose; birding time still reminds you of the old days, and the old hands that were there before you and the ones that taught you."

About eighty muttonbirders, most of them Aborigines, gather from the islands or elsewhere in northern Tasmania for the muttonbird harvest. ("First thing you do," says Kim Stonehouse, "is take a big lungful of air, to smell the birds in the rookery.") The five-week season is an opportunity to meet friends and family not seen since the previous year. Each year, the shed owners usually invite back workers of long standing who know that there is always a job for them.

Most of the Aboriginal muttonbirders, whether they are operators, catchers, or shed hands, are over forty and were raised on Cape Barren Island. They are usually unemployed for the rest of the year, living on welfare checks. Muttonbirding provides them with a means to accumulate enough money to buy major household goods or pay off debts. As one muttonbirder said, "You work five weeks for that money; she's gone in a couple of days."

What future the industry has is a question that few muttonbirders ask themselves. In my interviews of both Aborigines and Europeans on their experiences, I found that most held no hope for muttonbirding because of the disillusionment of the younger generation. This feeling was particularly strong among middle-aged Aboriginal muttonbirders. "The people have changed," Doug Lowery told me. "There's too many drugs and whatever going on in the world today. Unless they got a beer or something, they are not interested." But Furley Gardner, an elder in the Aboriginal community in Tasmania, still has hope despite the bureaucratic formalities:

> I don't think it will ever die out. But the way things are today, like taxation, employment or unemployment—it's putting pressure on a culture that they want to do. . . . The majority of Aboriginal people are not into this business of what you should do and what you shouldn't do. To them they just like to be free, they just like to go and come back. ☐



Each high tide brings a legion of turtle

La Arribada

More than 150,000 sea turtles gather annually to lay their eggs on a single Costa Rican beach

Text and photographs by Fred Bruemmer

The turtle armada arrives with the high tide in the gray light of dawn. Slowly and ponderously, first hundreds, then thousands of female olive ridley turtles march up the beach. The arrival, or *la arribada*, as it is called in Spanish, is the synchronous mass nesting of more than 150,000 sea turtles, the largest such gathering in the world.

Of the world's eight sea turtle species, only the olive ridley, the most abundant of all marine turtles, and the much rarer Kemp's, or Atlantic ridley, stage such *arribadas*. Only five beaches in the world are known sites of olive ridley *arribadas:* two in India's Orissa Province, another at a remote spot in Mexico, and at two points on the Pacific coast of Costa Rica—Playa Ostional and, fifty miles farther north, Playa Nancite.

At Ostional, a remote, isolated village in Costa Rica's Guanacaste Province, the turtles arrive throughout the rainy season—July to December—but peak *arribadas* occur in September or October, usually within a few days before or after the first or last quarter of the moon. At that time, the people of Ostional wait impatiently for the great arrival to begin. They exploit the turtles, but they also protect them, because without turtles, they say, "our village would die."

The turtles have migrated for months across thousands of miles of ocean, from Peru in the south, from Mexico in the north, and from open ocean, to reach the half-mile-long strand. But before coming ashore, they mass and mate offshore. For two carapace-encased creatures to make love in a wave-tossed sea is evidently difficult, but as marine biologist Archie Carr wrote, "Sea turtles in love are appallingly industrious." While they slip and grip and grapple a few miles from shore, 400 villagers and 200 black vultures wait near the beach for the great arrival.

At first, on dark nights at high tide, a few female turtles venture ashore. They are timid, skittish, and afraid of light; a sudden movement or even the flame of a match will scare them back into the sea.

Slowly the momentum builds. When I took these photographs last year, I watched as the number of breeding females increased on successive nights: 20, 50, 100; one night we counted more than 300. On the day after the quarter moon, Jorge Ballestero, the resident biologist, predicted, "Tomorrow the *arribada* will really begin."

The next day, at high tide in broad daylight, they hit the beach in serried ranks, struggling through the surf and crawling laboriously ashore. Now they had no fear. Nothing could deter them from repeating their ancient mission of laying eggs in this narrow strip of fine-grained obsidian and pumice sand.

The great strain of moving their armored bodies, no longer supported by water, made breathing difficult. Wheezing and gasping, the turtles rested, then struggled onward and upward, frequently dipping their noses into the moist sand as if to confirm that this was, in fact, their ancestral beach.

Each year, wave upon wave of turtles land and lumber upward to the flat portion of the beach, until Playa Ostional, looking like an old cobblestoned boulevard, is paved with turtles. As each female turtle selects a spot on the beach that she finds suitable, she begins a sequence of motions that is inflexibly stereotyped. With sweeping motions of her front flippers she creates a shallow "body pit." Then, using her hind flippers alternately, she scoops out sand and flings it aside. As she scoops and flings, scoops and flings, the hole becomes deeper and deeper. She stops, wheezing and grunting with the exertion, then continues to dig, creating a flask-shaped egg chamber as deep as her hind legs can possibly reach.

In about half an hour, the egg chamber is complete. The female's hind flippers encircle the hole, the rear end of her carapace covers it (thus discouraging vultures that want to steal eggs), and she begins to lay her clutch of soft-shelled, gleaming white, ping-pong-ball-sized eggs—always about a hundred of them.

"There is a great deal of biology packed into that figure," wrote Archie Carr in his classic book *So Excellent A Fishe.* "The whole race and destiny of the creature are probably balanced at the edge of limbo by the delicate weight of that magic number of eggs." Any more would put too great a strain on the turtle. Any fewer and predators could prevail, and the species might possibly vanish.

Her clutch completed, the turtle rests briefly, then pushes sand into the egg

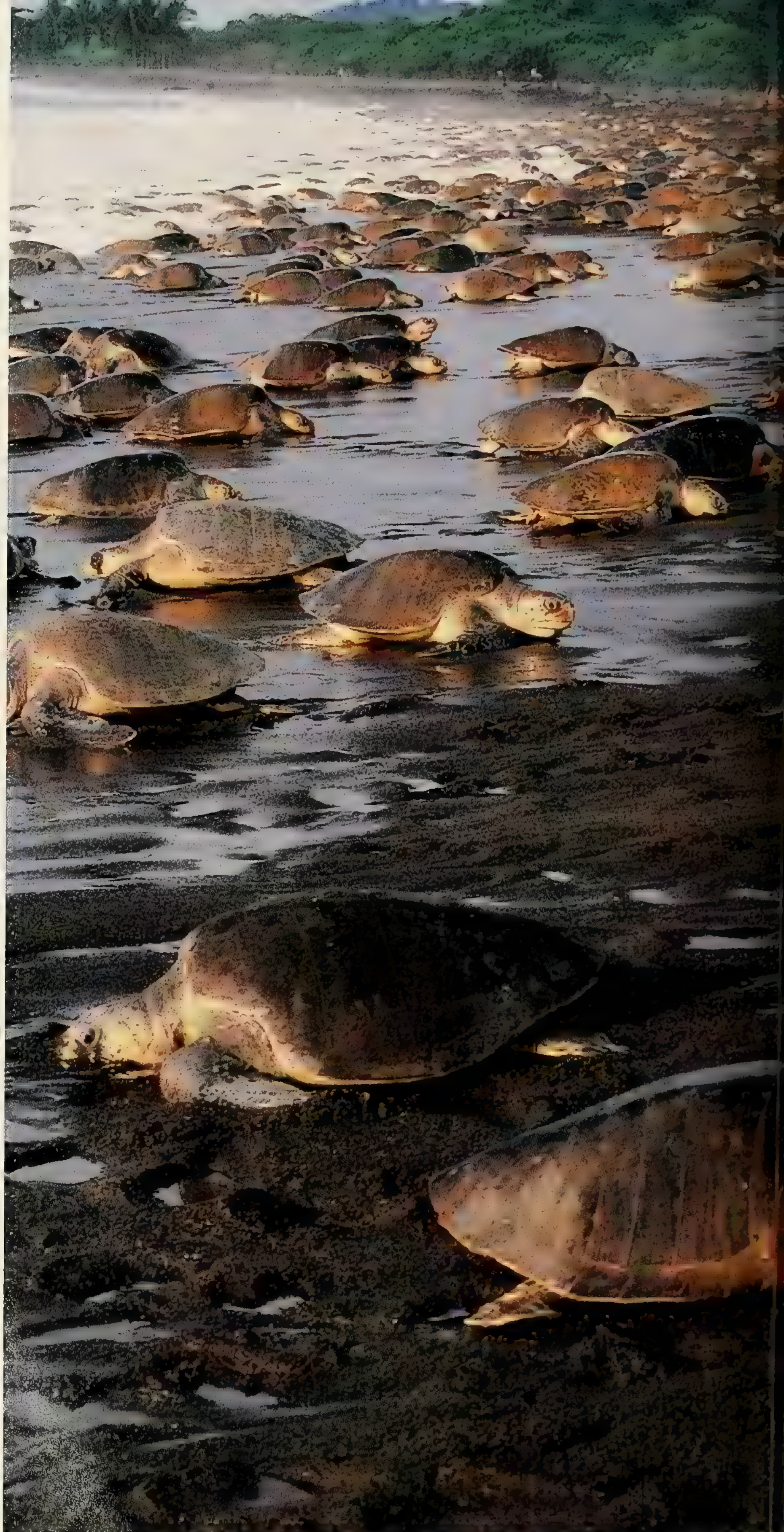
compulsive, driven army of reptilian tanks.

chamber with her hind flippers. She rocks from side to side, packing the sand down with her lower shell; scatters sand with flailing flippers to efface all signs of her presence; and slowly lumbers back to the sea, nearly always by a path slightly different from the one by which she arrived.

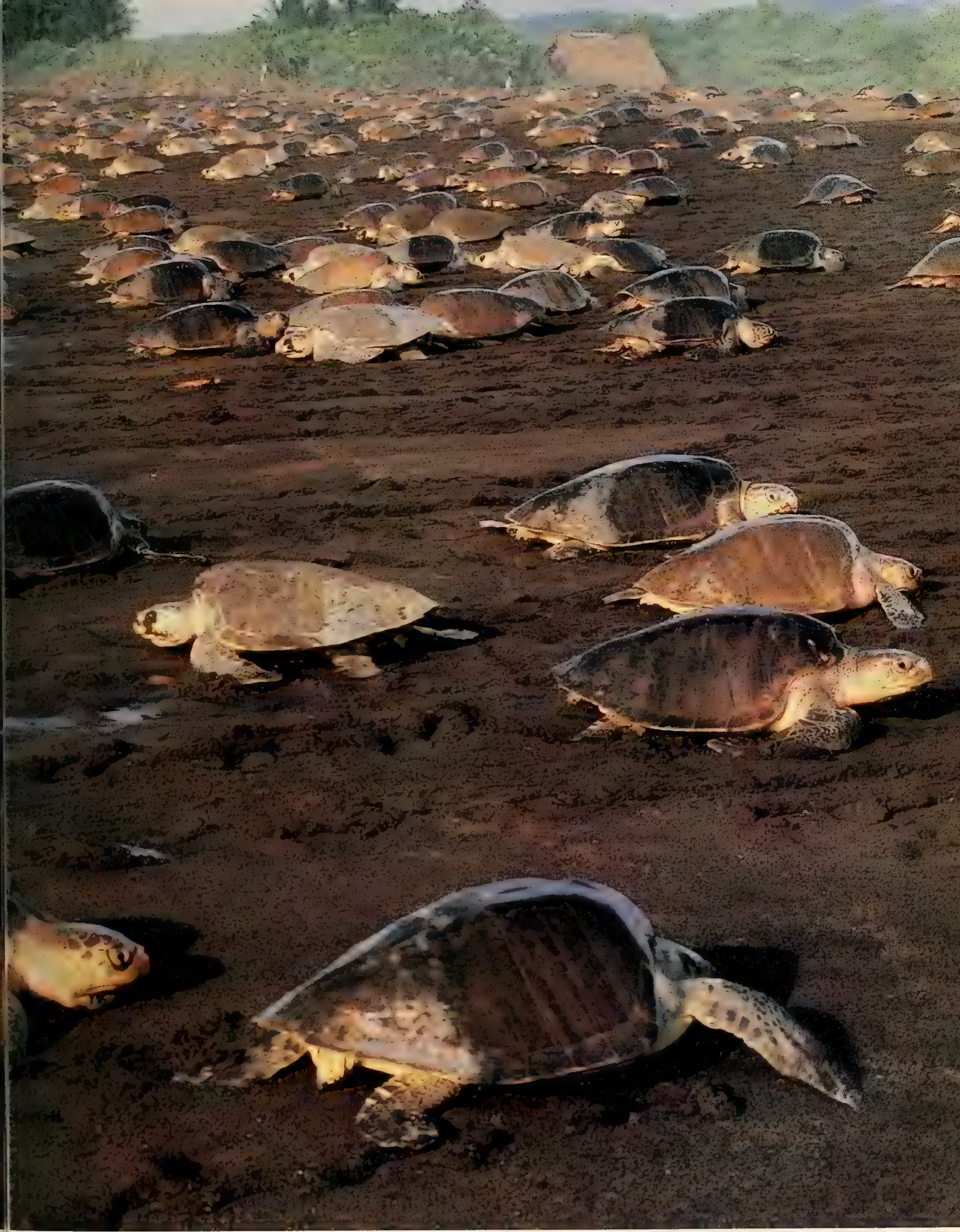
Most *arribadas* last four days, with each high tide, day and night, bringing new legions of turtles—a compulsive, driven army of reptilian tanks. Last to arrive are the halt, the lame, the sick, the injured: turtles so ancient (some may live to a hundred years) they can barely crawl; turtles terribly disfigured by fungal growths; turtles that have swallowed shark hooks and now, near death, try desperately to creep ashore and lay their eggs; and turtles whose hind flippers have been bitten off by sharks and that inch their way up the beach with infinite labor—a totally futile effort, for lacking hind flippers, they cannot dig egg chambers: they lay their eggs on the sand, and the vultures eat them.

In four days, 150,000 to 200,000 olive ridley turtles have swarmed ashore at Playa Ostional to lay their eggs. Then, as suddenly as it began, the *arribada* ends. On the fifth day not one turtle remains on the beach.

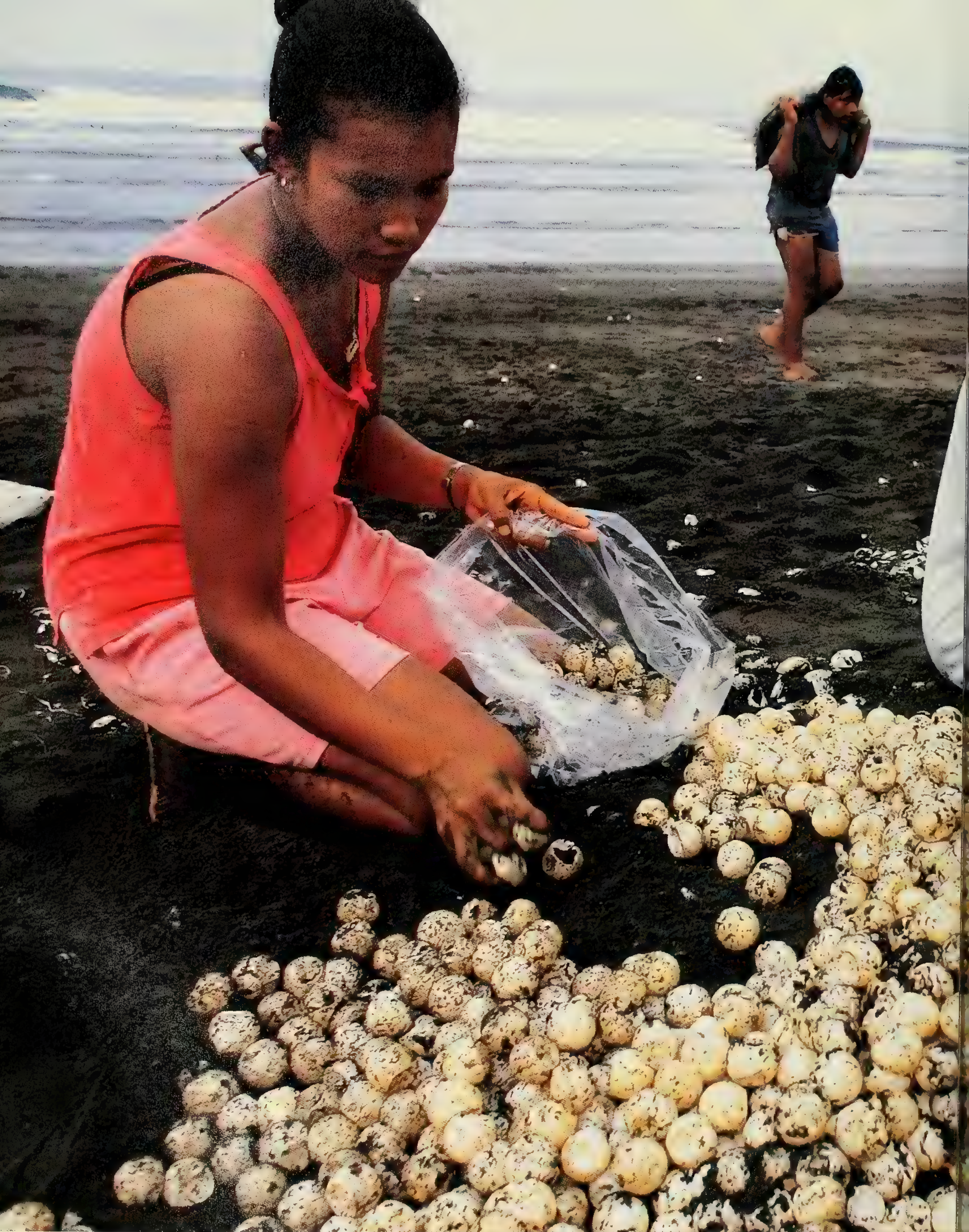
After such a spectacular invasion, this total absence is somehow eerie. The beach is empty and clean, and the vultures roost sleepily on their favorite trees. To me, the hectic four-day *arribada* already seems like an illusion; but for the villagers, it has all been very real, for turtle eggs are the basis of their economy.



Wave upon wave of olive ridleys lumber upward out of t



until the beach is paved with these eighty-pound turtles.



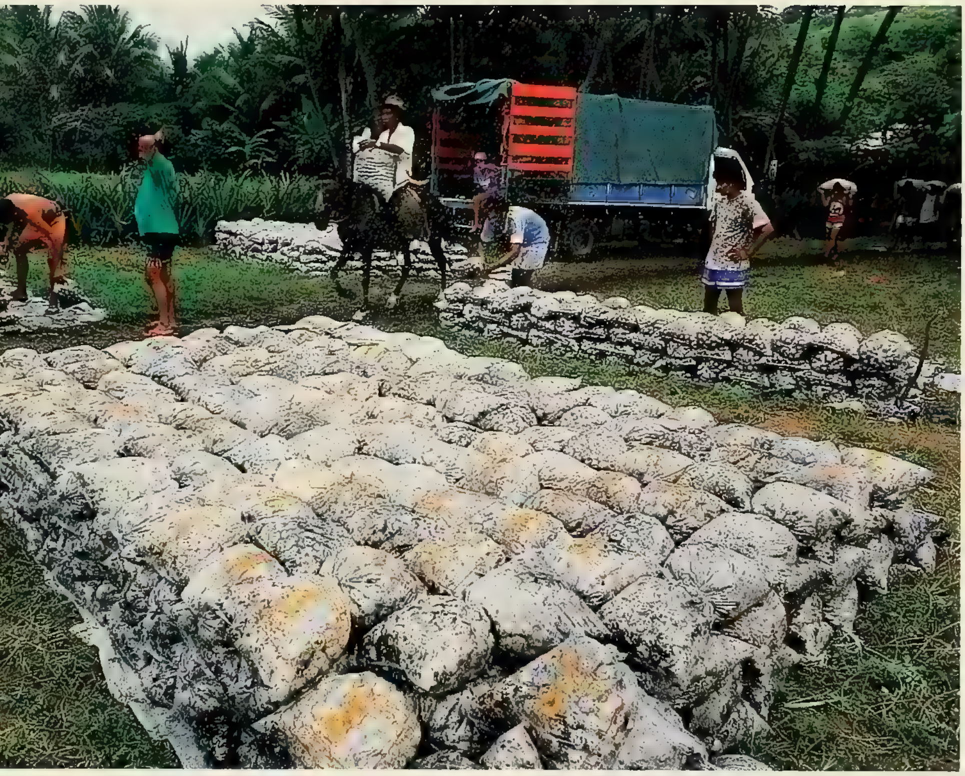
An *arribada* is part fiesta, part hard work. The men probe

In 1987, after a long and often acrimonious debate among scientists and politicians, the Costa Rican Congress approved a management plan legalizing the harvesting of turtle eggs on Playa Ostional. In all Costa Rica, only these villagers may legally harvest and sell sea turtle eggs. This unique legal right is vested in the members of the Development Association of Ostional (ADIO), under the supervision of the University of Costa Rica. All adults (men and women above the age of fifteen) belong to the association. "Members of the ADIO collect the eggs," says its president, Gerardo Ordoñez, "and all share in the proceeds."

The University of Costa Rica's sea turtle project prepares studies of the turtle population and ecosystem and regulates the sustainable harvest. Villagers administer and execute the project; they control the harvesting and marketing of eggs, police the beaches, and carry hatchlings to the sea, bypassing poachers and predators.

Ostional's residents, close-knit, conservative, and practical, have solved the problems of exploitation and protection with skill and little fuss. The special circumstances surrounding the *arribada* have enabled them to set up clear and rational guidelines for the harvest. There are many superb beaches near Ostional, but for reasons known only to turtles, they use only one, half-mile-long beach. There the number of breeding, digging turtles is high (more than 200,000 during a peak *arribada*), and each wave of landing turtles may dig up and destroy a large proportion

ands with shuffling feet, while the women haul out the eggs.



(70 to 80 percent) of eggs laid by earlier arrivals. The result is a gooey, putrid mess, which becomes a perfect breeding ground for insect larvae and fungi that infect eggs and kill embryos.

To prevent this, the villagers may harvest all eggs laid during the first thirty-six hours of an *arribada,* about 3 million eggs in a season, or 10 percent of the 30 million laid by the sea turtles each year in the sands of Playa Ostional.

As soon as most turtles that arrived with the day's high tide have left the beach, the harvest begins. Teams of men and women divide the beach into quarters and work them intensively. For the villagers, an *arribada* is part festival, part very hard work. The barefoot men shuffle in an odd two-step dance across the sand. Wherever it yields a bit, they dig deep down into the moist warm sand to expose the egg chamber, then continue their probing dance across the beach. The women, many wearing bright fiesta dresses, haul out the eggs and fill eighty-pound sacks with them. Young men carry them to the shoreline, where men on horseback bring them to a shaded collection center. (Horses are not allowed high on the beach, where they could crush eggs.) Methodically, the villagers empty the beach. All holes are carefully covered. Children clean the beach and remove all damaged eggs.

After thirty-six hours, the villagers have amassed 840,000 sea turtle eggs. To prevent spoilage, the egg-filled sacks are thoroughly washed in the sea. The eggs are then piled into great gleaming heaps on a nearby beach (so as not to bother the turtles on the breeding beach), dusted with sand to protect them and make them less sticky, and packed by women into strong plastic bags. There are 200 eggs in each bag, clearly labeled as containing the legally harvested turtle eggs of Ostional.

Fleets of trucks arrive to carry the harvest to towns and villages all over Costa Rica. About half the eggs will be used by bakeries, where they are prized over hen's eggs. The other half will be sold to cantinas (bars) where they are served raw as "bocas," or tidbits, with beer or with "guaro," a harsh, potent sugarcane liquor, a combination said to bolster the libido of male patrons. (The aphrodisiac idea may be baseless, but is deeply rooted in the ancient Maya culture of the area.)

The bargain that has been struck between the Costa Rican villagers and "their" turtles insures that the awesome *arribadas*—one of nature's grandest spectacles—will go on into the future. □

After the villagers have amassed 840,000 sea turtle eggs, th

rotect all subsequent hatchlings from harm.

THEY ASKED SO LITTLE—AND GA

Loved Ones

Photographs by Sylvia Plachy

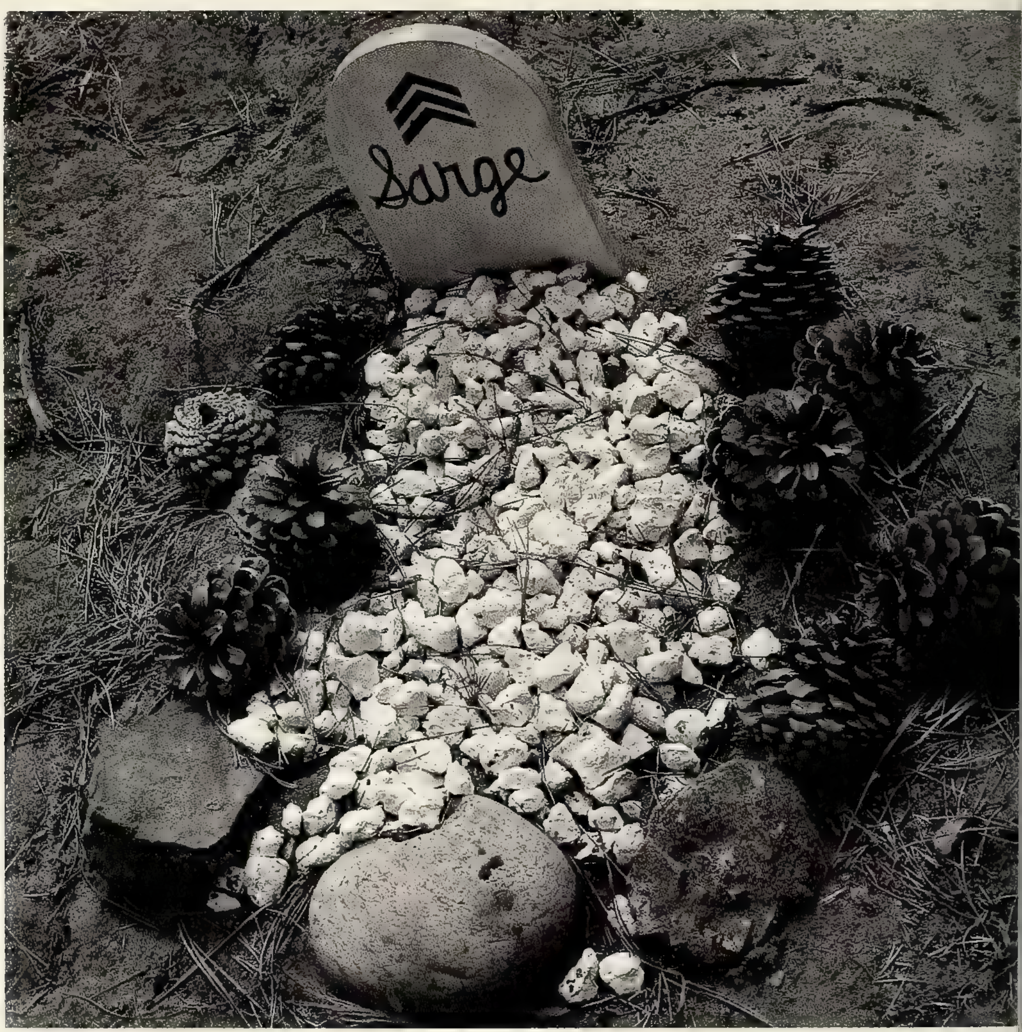
Text by Andrew N. Rowan

In his novel *The Loved One,* Evelyn Waugh conjured up a California pet cemetery, The Happier Hunting Ground, in order to satirize American attitudes toward death and dying. But it would be a mistake to associate memorials to dead pets with the excesses of modern life. One of the earliest-known pet burials was found in northern Israel. Dating back approximately 12,000 years, the excavated grave held the skeletal remains of an elderly human and a five-month-old dog. Whoever oversaw the burial had arranged the person's left hand resting on the shoulder of the puppy in an eternal gesture of affection.

In her travels, photographer Sylvia Plachy takes time out to photograph the places where people have left memorials to their pets.

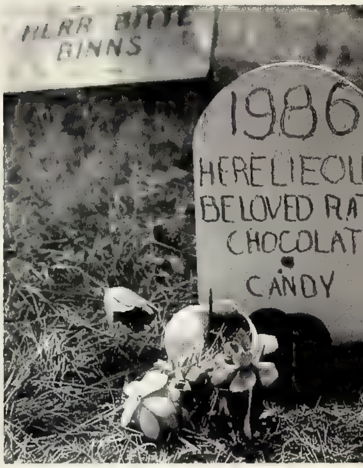
Andrew N. Rowan is director of the Tufts Center for Animals and Public Policy and editor of Anthrozoös, *a journal on human–animal interactions.*

When humans domesticated animals, starting some 12,000 years ago, the interdependence between them increased. Pets give humans signals about the natural world. Some people have speculated that the sight of roosting birds (or grazing herbivores or sleeping dogs) has a soothing influence on us because they signal the absence of danger.



Fifty-six percent of households in the United States have dogs and cats (only 35 percent have children). When these pets die, the grief is great. Bereaved owners have been known to engage the services of professional pet-loss counselors. Today, an estimated 400 to 500 pet cemeteries exist in the United States.

Many cultures have erected memorials to their pets and developed elaborate rituals to ease grief over the loss of animal companions. The Kalapalo Indians of Brazil nurture and protect pet birds. When the birds die, they receive the same burial ceremonies as infants who die before being named.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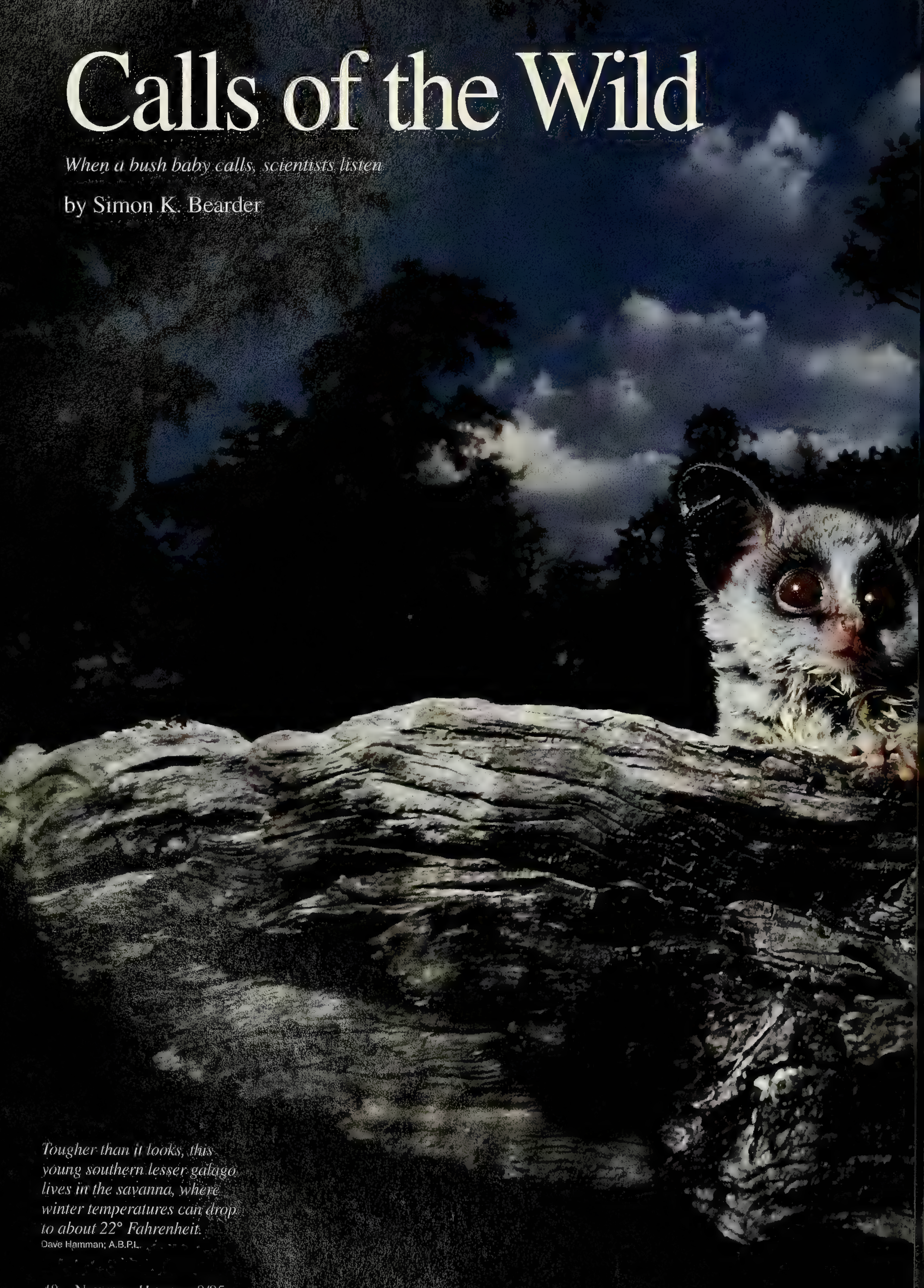
In pre-Christian Rome, both Ovid and Catullus wrote poems to commemorate the death of pets. The epitaph on an ancient Greek grave marker cautions passersby not to smile, "though this is the grave of a dog. My master loved me and buried me here with his own hands."

LITTLE
BIT
GLASSCOCK

Calls of the Wild

When a bush baby calls, scientists listen

by Simon K. Bearder



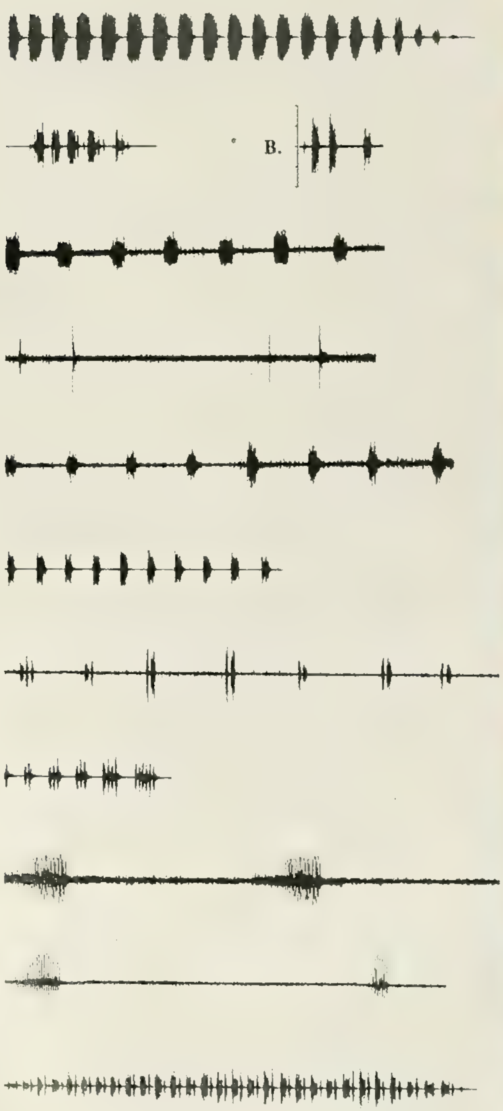
Tougher than it looks, this young southern lesser galago lives in the savanna, where winter temperatures can drop to about 22° Fahrenheit.
Dave Hamman; A.B.P.L.

The setting of the sun throws the African rain forest into deep darkness. For humans, driven by an almost irresistible urge to judge everything by sight, the lack of light is frustrating. But with vision so diminished, the ears come into their own, awakened to the wealth of sounds made by the many creatures of the night. Among the most vocal of these animals are the galagos, little primates, some small enough to fit neatly into the palm of my hand.

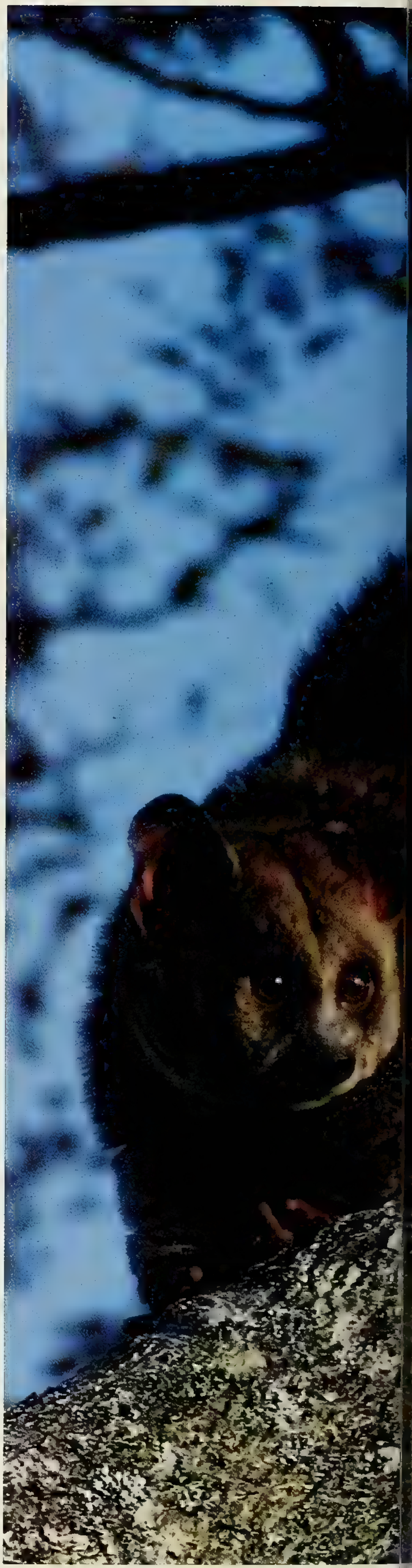
Found in sub-Saharan Africa, galagos live everywhere, from woodland savanna to primary rain forest. Attractive bundles of fur with flattened faces and long tails, the smallest species are mouse-sized, while the largest are about the size of cats but with fingers and toes equipped with nails instead of claws, reflecting their relationship to monkeys, apes, and humans.

Galagos hide during the day in tree hollows or well-camouflaged leafy nests and emerge at dusk to feed on insects, fruit, and tree gum. They are well adapted to their nocturnal life: huge eyes and a reflective layer of cells behind the retina

Galagos, or bush babies, are among the most vocal of Africa's night creatures.



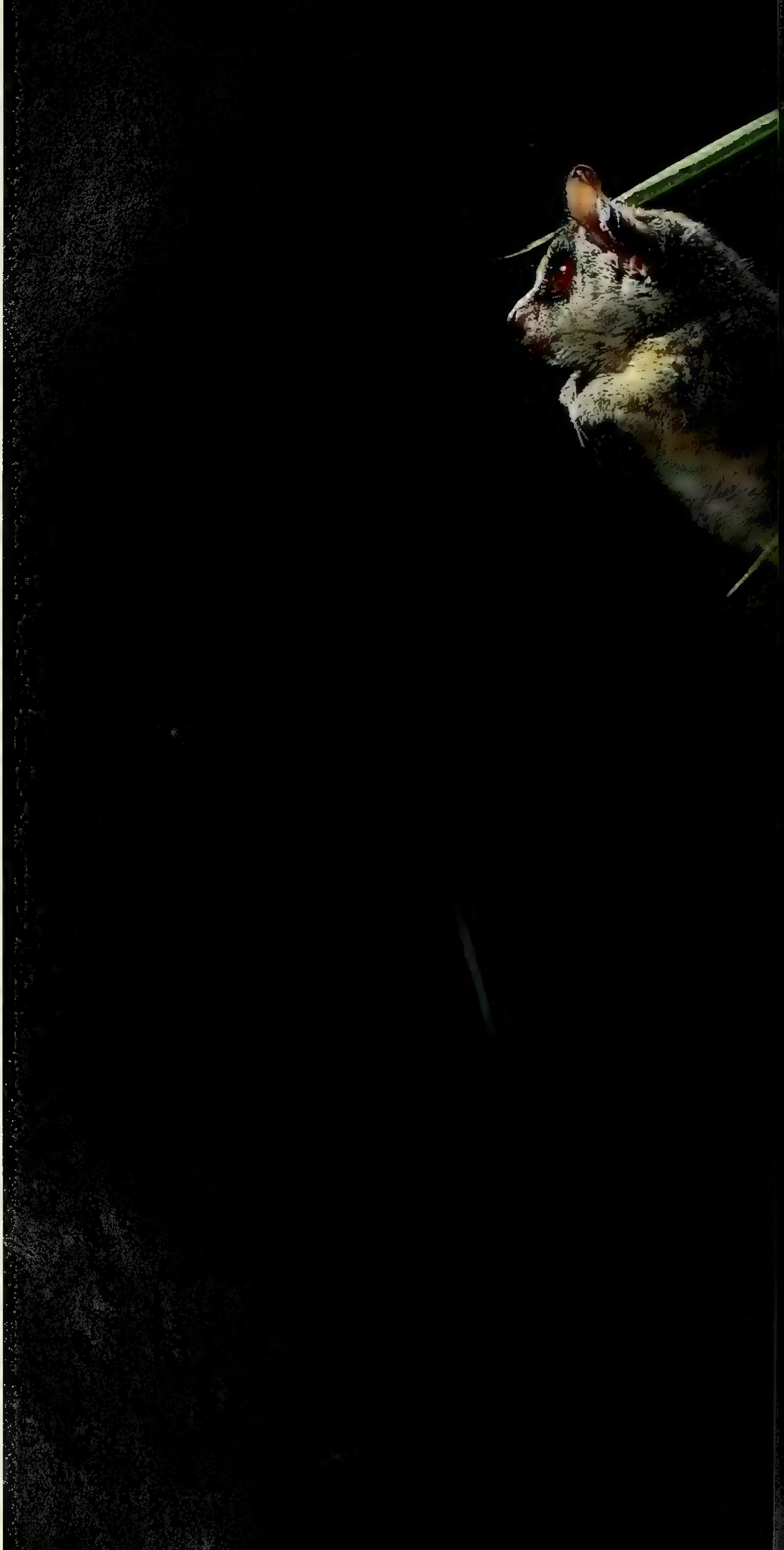
Oscillograms, right, show striking differences in the calls of species of galagos. Far right: A thick-tailed bush baby sets out at dusk for a night of feeding in the woodlands of Zimbabwe.
Oscillograms by Lesley Ambrose and Simon K. Bearder



Lee Lyon; Bruce Coleman, Inc.

Stephen Dalton; NHPA

Using its long tail as a rudder, a lesser galago can leap fifteen feet without coming to harm, even on the darkest night.



Barrie Britton

Demidoff's dwarf galago, above, inhabits the lower level of tropical forests in Gabon. A closely related species lives higher up in the forest canopy. Opposite page: Galagos use their big eyes and ears and acute sense of smell to check for signs of danger before crossing open spaces.

(called a tapetum) increases their ability to capture light. Independently moving ears help pinpoint the location of insects and dangers. Batteries of touch-sensitive hairs around the eyes and ears inform them about their surroundings, as does a remarkable sense of smell and a moist nose, which is joined by a groove to a special sense organ in the roof of the mouth.

Making their way through the trees, galagos hang, hop, run, and make prodigious leaps, sometimes spanning fifteen feet in a single bound. During their travels, which can cover more than a mile each night, they call frequently, each call carrying valuable information about their way of life and social behavior.

In 1968, I began a field study of galagos, paying particular attention to their vocalizations in the hope that I might turn up some new information on their ecology and behavior. Twenty-seven years later, I am still fascinated by the yells and squawks of these small mammals. The study of their vocalizations has not only made possible a better understanding of what they are saying to one another; it has also altered estimates of how many species there are—from a paltry half dozen to a known sixteen and a suspicion that there may be as many as forty.

Working with captive lesser galagos in South Africa, Annette Andersson, of the Department of Psychology, Witwatersrand University, was the first to recognize specific calls. She identified a total of twenty different calls, some brief and quiet, as when a mother was with her infants, and others, uttered in the presence of danger, that were raucous and given for up to an hour. Her study alerted me to the possibility of understanding many aspects of these animals' lives from their calls and paved the way for a succession of field studies throughout Africa, which I conducted with the help of several colleagues.

Working at night, using headlamps to pick up the extremely reflective eyes of the galagos amidst the dense vegetation in which they live, we still found it hard to observe the details of their behavior. We could, however, readily make tape recordings without disturbing the animals. Analyses of their sounds provided information about the makeup of the calls and the anatomy of the animals, for their sounds are influenced by the structure of the voice box and throat.

One of the galagos we have come to know well is the thick-tailed bush baby, which gets its name from its infantlike cries. In some parts of South Africa, people believe the strange sound is made by an enormous snake said to devour anyone who ventures into the forest at night. In reality, this call is important because it attracts companions and repels rivals.

Other calls made by this largest of the galagos express various degrees of anxiety and fear. In the presence of a potential predator, a disturbed bush baby will make knocking and moaning sounds. As the predator approaches, the knocks merge, or grade, into squawks, whistle yaps, and whistles, interspersed with bouts of chatter. The loudness of the calls and the pattern of repetition tell the listener—whether a leopard, another bush baby, or a researcher—that the caller knows danger is near, knows the nature of the threat, and knows how close it is. When a bush baby is actually under attack, it gives a blood-curdling yell that induces other bush babies in the group to come to its defense. Juveniles separated from their mothers alert others to their predicament with a distinctive buzzing call. All in all, we have identified a complex repertoire of eighteen thick-tailed bush baby calls, any one of which can transmit at least five different messages.

Lex Hes

Galago species can often be told apart by differences in their fingernails and toenails, above. Opposite page: Its reflective eyes aglow in the photographer's lights, a thick-tailed bush baby pauses on a tree limb in Kenya. Thick-tailed bush babies are widely distributed in sub-Saharan Africa—from Angola, in the west, to Somalia, in the east, to Natal, South Africa. Just how many species make up this group is not yet known.

Comparisons of vocal "fingerprints" may point to new galago species.

Galago calls also appear to vary depending on an animal's physical situation. At close quarters, animals attempting to establish social contact give high-pitched calls; when communicating over a distance, they utter low sounds, which travel farther. Because of their short wavelength, high notes are more easily blocked by leaves and branches. This may explain the relatively deep voice of Allen's galago, a species that inhabits dense undergrowth in the rain forests of Cameroon. Elegant galagos, living in the same rain forest but in the more open canopy, give high-pitched calls.

The more we came to know the behavioral ecology and vocalizations of one population of galago and moved on to the next, the more we realized that different species have been lumped together under the same name.

To help us make our way through the maze of galago calls, we converted the voice prints of all the loud calls characteristic of each species or suspected species into diagrammatic form (sonograms and oscillograms). Comparisons of these vocal "fingerprints" of populations from different areas of savanna, woodland, or forest show differences that may point to a new species.

The task quickly gets complicated. Distinct but closely related species will have similar voice boxes and thus very similar calls. And some vocal differences may simply be local dialects within the same species.

Fortunately, vocalizations are not the only way to tell species apart. Our team of researchers at Oxford Brookes University is examining correlations between calling patterns and other aspects of the animals' biology. In the laborator DNA extracted from blood, tissue, or hair fo licles is being used to measure the genetic dis tances between species or populations. Compar ison of the pattern of scales on the surface o hairs or detailed anatomical studies of galag hands, feet, ears, teeth, and other body part often show species-characteristic variations Some species, for example, can be told apart b the size, shape, and degree of spininess of th male's penis. Others have distinctively shape fingernails and toenails. The shape and pattern o face markings also vary between species.

In the last three years, research student Pau Honess and I have discovered that mouse-siz dwarf galagos from West Africa do not consti tute one species, as was long assumed from mu seum specimens, but two. Vocal differences i the animals we worked with prompted a close look at their appearance, and when individual of each species were placed side by side, their fa cial markings, body color, and reproductive or gans were clearly distinct. Thomas's dwar galago lives mainly in the forest canopy, whil Demidoff's dwarf galago stays in the under growth, where it travels around on much thinne branches. The museum animals were most likel collected from the undergrowth, where the were easier to see and catch; animals spotted i the canopy were probably assumed to be th same species.

Paul has since discovered four more previ ously unrecognized species in Tanzania. Judgin from their calls, one of these is closely related t a known species, but the other three appear to be long to a new group of galagos (the souther dwarf group) that until now has passed unno ticed. Unlike the dwarf galagos from Wes Africa, which attract their companions with cal in the form of a crescendo, the southern specie give repetitive sounds completely different i structure. Other calls are also distinguishable be tween the two groups, but within groups, eac species has its own unique blend of calls.

Fossil remains in Kenya show galagos hav existed for at least 20 million years. Once we un ravel how many species there are, where the are, and how they are related to one another, w hope to establish where they originated and ho they spread through Africa.

We also expect to find out which galago pop ulations and species are most in need of conse vation. Agriculture, urban expansion, and log ging are fragmenting and destroying Africa forests at an alarming rate. If more than tw dozen species of galagos exist, then each i likely to exist in fewer numbers, perhaps hav more restrictive habitat requirements, and thu be more vulnerable than was realized. And if w have so seriously underestimated the number o galago species, how much have we missed i less well known groups of animals? □

The Early Bird Gives the Sperm

Spotted sandpipers on a Minnesota lake reveal the secrets of their breeding success

Lewis W. Oring

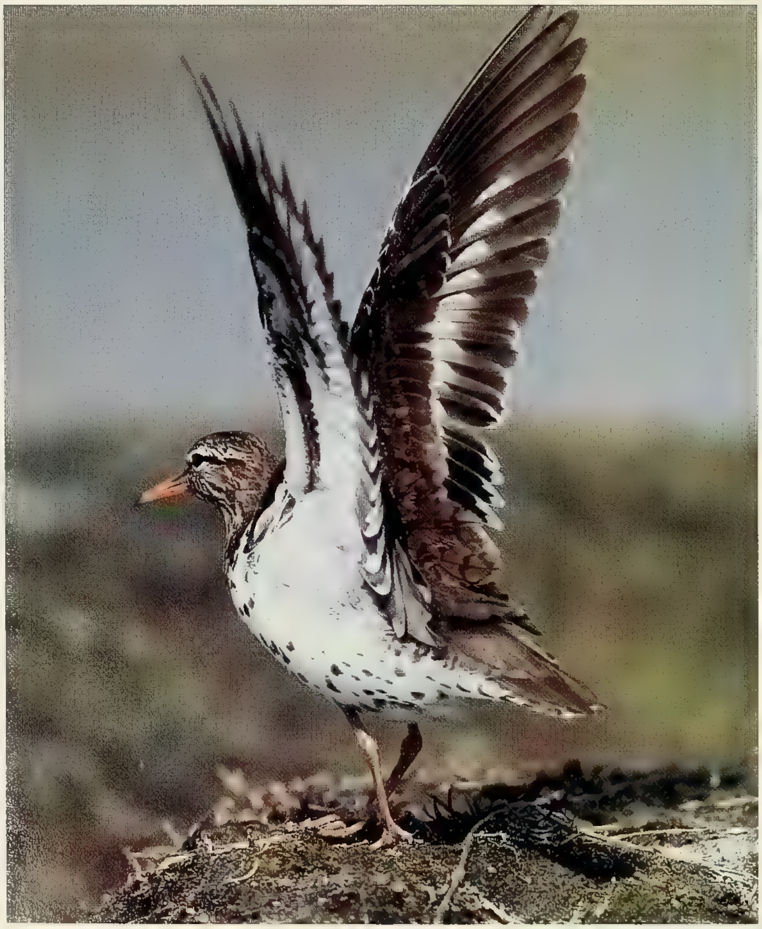
The female spotted sandpiper left her mate sitting on their clutch of four eggs and headed into a neighboring territory on the lakeshore. She was eager to attract another male and ready to fight with the resident female for his attentions. The vicious, hour-long battle that ensued was typical. The two females grappled on the ground, in the air, even in the lake. Each tried to flutter over the other—the better to peck at her head and perhaps gouge an eye—or to grasp one of the rival's slender legs, flipping and effectively crippling her. In this battle, the intruder succeeded in driving her neighbor, bleeding from the head and breast and with an injured eye, from the territory. To the victor belonged the spoils—the opportunity to mate with the vanquished neighbor's male.

Another female I observed had no need to intrude into a neighbor's territory to achieve her goal. While one male was dutifully sitting on her eggs, she flew up and launched into aerial flight songs. This proved irresistible to nearby males. One of them even deserted his mate and clutch of eggs and headed for this sandpiper siren's territory.

Spotted sandpipers are one of a few species of birds that are sex-role reversed: females are aggressive and play the more active role in courtship, while males provide most or all of the care for the young. Among sex-role reversed species, a small group are classically polyandrous, that is, the socially dominant females mate with multiple males, each of which tends a clutch of eggs. In 1871, Charles Darwin predicted avian polyandry, which in Greek means "many males." He knew that species in which females cared for the young and males were large and brightly plumaged tended to be polygynous, with one male having many mates. He surmised that where males were responsible for parental care and females were the larger or brighter sex, the species would be polyandrous. But not until a hundred years later was the existence of polyandry documented. Most sex-role reversed, polyandrous species are sho
birds; the best known are the northern
cana, several species of phalarope, and t
spotted sandpiper.

In 1975, field biologist Steve Maxs
and I headed to Little Pelican Island,
Minnesota's Leech Lake, to study t
spotted sandpipers that bred there. I had
idea that I was embarking on the first
eighteen summers living and researchi
on the lake. At first, the island seemed li
a biological paradise. Phenomenal may
and midge hatches and the insects' sub
quent die-off left inches of carcasses
fertilize the soil, creating an incredi
rich environment a
plentiful food for breedi
birds. Our camp w
shaded by some of t
largest elm trees
earth—up to eleven feet
diameter. Plant growth a
peared almost tropic
with ten-foot-high c
parsnips, ostrich ferns t
dense to walk throug
and a forest floor cove
with jack-in-the-pul
Dutchman's-breeches, a
lily of the valley.

By the time our stud
ended, in 1993, the tr
were all dead, victims
Dutch elm disease, a
some of the larg
branches, which su
ported a bald eagle's ne
had crashed to ear
When we began our stu
ies, no mammalian pre
tors inhabited Little Pe
can Island. Eventual
weasels colonized the
land and decimated t
sandpiper population.
was the end of an era.
the legacy of the spot



A female spotted sandpiper stretches her wings in a threat display.

All photographs by Tom Vezo

TECHNOLOGY UPDATE

With convenient wireless installation, two lighting systems offer the brightest solar light ever available!

Alpan's industrially-proven solar technology harvests the power of the sun to protect your home and family.

by Bob S. Garrard

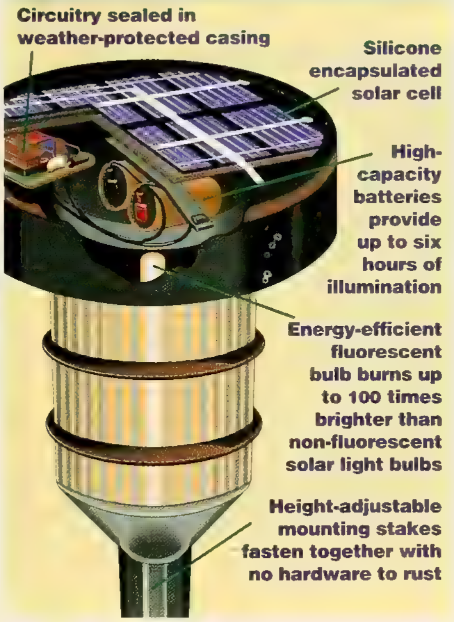
How many nights have you had to negotiate a dark walkway to the door hoping you wouldn't trip on something? Or how often have you stood in the dark fumbling with keys? If you're like me, you leave the porch light on all day, but you still have to find the porch in the dark!

Now there's a better way to come home to the warmth and safety of a well-lit home. Alpan, in colaboration with Siemens, has developed two new lighting systems—the Solar Pathway Light and Solar Sensor Light.

The fluorescent advantage. Built with a fluorescent bulb, the new Solar Pathway Light provides the maximum amount of illumination while using a minimum amount of energy. In fact, the unique fluorescent tube is up to 100 times brighter than non-fluorescent solar-powered lights.

Industrial technology. Alpan has put the *single crystal cell*, the same powerful cell found in industrial power modules, to work for you in the Solar Pathway Light. Using the energy collected by the cell during the day, the power source is charged. At night, the built-in photo sensor detects darkness and automatically turns the light on to provide up to six hours of illumination.

The brightest solar lighting system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No bills, no wires. The Solar Pathway Light can be installed in minutes. Simply twist the two parts together and put the light in the ground. All of the connections are internal, so there are no wires. And because these lights store and use energy from the sun, you'll never pay for outdoor lighting.

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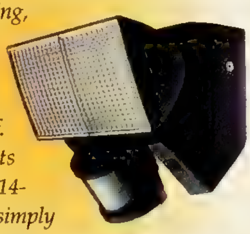
Factory-direct offer. This advanced solar lighting technology would retail for hundreds in stores. But through this special factory-direct offer, you can get the Solar Pathway Light for just $59. Order extras, and receive them for just $49. The Solar Sensor Light is available for only $79 with additional lights costing only $69 each. Take advantage of this special offer to add beauty and safety to your home and yard.

● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ●

Solar Sensor Light for extra security. *Equipped with the same powerful technology as the Solar Pathway Light, the Solar Sensor Light offers you and your family extra protection for your home and outbuildings. This powerful floodlight uses solar power to light your yard with a powerful quartz-halogen bulb. And it has a built-in heat and motion sensor. With no timers or switches to set, this light automatically switches on when triggered and stays on after you leave for 30 to 60 secconds. The adjustable 30 to 60 second delay ensures that you'll never be left in the dark. With no wiring, it's easy to install. The solar panel mounts directly on your roof. The light mounts anywhere. The 14-foot plug-in cord simply connects the two. The solar storage system is so powerful it will switch on as many as 120 times with just a single full charge. And it's able to run for up to two weeks—even if there's no sun.*



Economical and dependable, the Solar Sensor Light has a built-in heat and motion sensor.

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sandpipers of Leech Lake is the wealth of natural history secrets they revealed.

Spotted sandpipers are the most widely distributed sandpiper in North America. Unlike many other shorebird species, which nest in the Arctic, spotted sandpipers breed south of the tundra, often along rivers and on islands in large lakes. Because it was uninhabited and free of mammalian predators, Little Pelican Island was especially attractive to the sandpipers. Our first step was to color-band the birds so that we could identify individuals. Although they are not flashy, the females have more conspicuous spots and are larger (about 2 ounces) than males (about 1.6 ounces), which allows them to be socially dominant. This information enabled us to determine the sex of the birds in the field, especially important when observing pairs. (That males are always on top during copulation—not always the case for shorebirds—also helped.) As soon as we had marked, known-sex birds, the surprises began.

Among migratory birds, males generally arrive on the breeding ground before females. My research team and I found that, in spotted sandpipers, older females arrive first, from about May 10 to 20, from their wintering grounds in Central and South America. They then proceed to claim territories. Young females and older males fly in about five days later, and young males bring up the rear, arriving from May 20 to early June. (If a spotted sandpiper survives its first year, it will live, on average, to the age of three and a half; one of our males lived nine years.) Spotted sandpipers were the first long-distance migrant species in which the phenomenon of females arriving first on the breeding ground was recorded.

We reasoned that perhaps other, more subtle aspects of the spotted sandpiper's life history might also be unusual. Over the years, this has proved to be the case. In most bird species, the males are faithful to a breeding area; we found that female spotted sandpipers are just as site-faithful as their male counterparts. We could count on many of the same males and females returning year after year to Little Pelican or other nearby areas. We also discovered that while their mates are incubating, females that already have one territory make reconnaissance flights across the island and to other potential breeding grounds, up to three and a half miles away, gathering information about sites with a high density of males and, therefore, potential mates. Females that are unable to lure males to their home territory will later use this reconnaissance information to select future breeding sites, either in the same season or in years to come.

At least some aspects of sex-role reversal in spotted sandpipers are hormonally moderated. We measured their levels of testosterone, associated with male aggression in many bird species, and levels of the pituitary protein hormone prolactin, which has been shown to promote incubation. These studies showed that the males have higher prolactin levels than females. Spotted sandpipers were the first bird species for which this was documented; higher prolactin levels have since been found in two other sex-role reversed species, red-necked and Wilson's phalaropes. When the first egg of the spotted sandpipers' four-egg clutch is laid, prolactin levels of males rise rapidly, and during the next two days, testosterone levels plummet.

Spotted sandpiper females are aggressive. Males care for the young.

At this point, the males begin the twenty to twenty-one days of incubation. Males care for hatched young for three weeks or longer, brooding them under their wings (the young are precocial and can feed themselves). Females may help in incubation and may defend the nest, usually a scrape on the ground lined with vegetation, by sounding an alarm and attempting to distract predators. Females are more likely to provide some auxiliary care for their last clutch of the season and most are quick to shirk any care of early clutches when an opportunity to take another mate arises.

A good territory—one that is familiar, has hiding places in which to elude predators, and provides plenty of food for adults and young—is well worth guarding. Early on in my observations, I believed that having a good territory helped females get access to mates. As I obtained long-term data on known individuals, I realized that the situation is more complex. Some females acquire mates through the quality of their territory, while others compete physically for males. Young females rarely have more than one mate in a season, while older females tend to mate with more than one male and are also more likely to sequester two males at once (simultaneous, as opposed to serial, polyandry). Having multiple mates and laying clutches of eggs for each is no small task. The most impressive display of such behavior that we observed occurred in 1975, when a female laid five clutches, three for one male, and one each for two additional males. These twenty eggs weighed four times the female's body weight and contained ten times her total body calcium. This is equivalent to a human female producing a five-hundred-pound infant.

How might sex-role reversal have evolved in spotted sandpipers, what does the female gain, and why does the male undertake the bulk of nesting responsibility? Generally, the reproductive success of birds is measured in terms of the number of young raised to maturity. The first step on this road to success is copulation. Extra-pair copulation, in which a bird copulates with others in addition to its social mate, has been reported widely and can account for a considerable proportion of the eggs fertilized. Early reports tended to regard this as a male mating tactic. We wanted to investigate

A pair of spotted sandpipers take the first step on the road to parenthood. Females mate with multiple males.

extra-pair copulation as a means by which females could increase the quality of their offspring and their reproductive success. If a female perceives that a neighboring male is of higher genetic quality than her present mate, she may switch mates or solicit copulations from that neighbor.

My observations indicated that female spotted sandpipers are in control of mating. They solicit extra-pair copulations and disallow them at will, sometimes thwarting a mounting attempt they had previously solicited. To find out more about the dynamics of extra-pair copulation for both male and female spotted sandpipers, I obtained DNA from thirty-four spotted sandpiper families. The DNA profiles of eleven of the chicks indicated that one or both of the social parents were not the genetic parents. In ten of these cases, a previous mate of the associated female accounted for the fertilization. However, these previous mates had not copulated with the females in weeks and in several cases had been absent from the island during this time. We kept track of all color-banded birds. In some instances, we knew that the genetic fathers, at the time of fertilization of these chicks, were sitting on nests on a nearby island or on the more distant mainland.

How could these absent males have fertilized these eggs? This puzzle was solved when we determined that females were storing sperm from prior mates for up to thirty-one days before it was used to fertilize eggs. While this phenomenon had been reported in domestic birds, this was the first case among wild birds in which long-term sperm storage was shown to have resulted in fertilization.

This helped answer the question of why second-year and older males invariably arrive on the breeding ground earlier than they did as yearlings, and before younger males. In birds, age is often an indicator of genetic quality. Older birds have proved that they are survivors, able to withstand the rigors of migration and nesting. Female spotted sandpipers, which arrive first at the nesting ground, essentially always pair first with older males. As the season progresses, females are increasingly likely to pair with yearlings. But by storing the sperm of their first mates, the females retain sperm of older males, which is, on average, of higher quality. This sperm is used to fertilize late-season eggs that are cared for by unsuspecting yearling males.

Tim Birkhead, of Sheffield University in England, and Anders Møller, of the University of Copenhagen, who pioneered the study of sperm-storage in birds, have recently emphasized the possibilities for female control over the fertilization process, even in birds that are not sex-role reversed. Jim Briskie, of Queen's University in Ontario, has found that female shorebirds have thousands of sperm storage vacuoles located at the vaginal junction of the cloaca. Our studies, showing that stored sperm results in late-season males being cuckolded by a female's early season mate, indicate that such storage may play a more important role in shorebird natural history than previously imagined.

Females were storing sperm from prior mates for up to thirty-one days before using it to fertilize eggs.

While both males and females initiate copulation, the females determine the frequency and duration of copulation and potentially the size of the ejaculate with which they are inseminated. They also determine the timing of copulation, that is, whether or not it occurs around the time of ovulation. In addition, they appear to influence the fate of inseminated sperm through muscular contractions that increase the chances of sperm being ejected from, or propelled up, the reproductive tract toward the sperm-storage tubules.

Although females appear to have won the "battle of the sexes" in terms of controlling fertilizations, 89 percent of the offspring in our studies were not the product of stored sperm. This suggests that control is incomplete. Perhaps the physiological manipulation of sperm is not foolproof or not every old male is of high quality. We have also found that not every second or third mate is young.

Our discovery that the sperm of early, older males is often stored explains why older males subject themselves to the vagaries of early-season weather and attendant short food supplies. It also sheds light on the evolution of polyandry. Scientists had been at a loss to explain why males would accept full incubation responsibility rather than seek extra matings. Now we know that in addition to incubating eggs, older males sire offspring that are simultaneously being cared for by younger males, and thus seem to give up nothing in providing parental care. They fertilize their mate's first clutch, and often some of her later eggs. Meanwhile, late-season males make the best of their situation, until they too are older.

If females control mating to boost their reproductive success, what could the vanquished female—driven from her mate and territory—do to recoup her loss? Recovered, she returned home late in the season. She found her old mate tending the nest of yet another female and proceeded to help him raise chicks that were not hers and possibly not even his. The two appeared to have forged a friendship, not a tactic I associated with the drive and the necessity to reproduce. But this seeming self-sacrifice on the female's part turned out to be a form of long-range planning. The following summer, when both birds arrived on the island, they quickly mated and went on to raise healthy young spotted sandpipers. After eighteen years of studying these birds, and some 125 years after Darwin predicted polyandry, we are still discovering the ways in which natural selection molds the life histories of animals. □

At Cedar Beach on Long Island, New York, a spotted sandpiper takes time out from courtship to indulge in a vigorous bath.

Food Chain

I'll have what he's having

by Roger L. Welsch

It's no secret that cultural goods move freely and frequently, maybe inevitably and constantly, from one level of society to another, often improving in the process. High fashion starts in an almost freakish form as *haute couture* worn by models in a Paris fashion house and winds up in a considerably more sensible form in a farm wife's shopping cart at the Grand Island Wal-Mart. Esoteric arguments common to the classrooms of Harvard Law School echo in a courtroom in Los Angeles and are next heard coming from a mechanic's mouth in Eric's Big Table Tavern in Dannebrog. ("You bullheaded dipstick—Ito says she can't be argumentative in her opening statement and should save it for direct examination, and he should know if anyone does!")

The movement is upward as well as downward, with phenomena and artifacts of everyday culture rising to be reborn or re-expressed or preserved in elite, more elegant contexts. Antonín Dvořák, for example, used Slavic folk themes in his musical compositions. Medical science continues its exploration of traditional medicine for systems and substances unrevealed in its own laboratories. And no one is surprised to find Creole gumbo and southern-style spareribs listed on menus in the finest restaurants, along with patés, mousses, and sorbets. In fact, my impression is that the predominant flow of foodways is upward in the cultural stream, perhaps because the rich are just dying with curiosity to sample some chow, while the poor are already quite familiar, thank you, with cuisine.

After all, the poor—the laborers, servants, domestics—are the ones who historically have prepared and served the food consumed by the wealthy. Do you imagine for a moment they haven't been sampling some of those foods they are preparing and serving? I grew up in a very modest home; my parents were laborers. We never went hungry but our foods were fairly pedestrian—meat, potatoes, rye bread, and occasional ethnic dishes, such as pirogi (a meat and cabbage turnover), *schnitzsupp'* (dried fruit soup), and *rivelkuche* (sweet breakfast bread). But my mother sometimes worked as a domestic and now and then she helped prepare food for parties in the homes of her rich employers. She compiled elegant trays of hors d'oeuvres with canapés of caviar, lox, anchovies, and capers. Whenever I knew Mom was working one of these parties, I would fight to stay awake until she came home, knowing she would bring back a bag of elegant and exotic morsels.

What strikes me, as scion of uncounted generations of peasants and churls, is that for centuries we have been sampling the foods of the rich on a fairly regular basis, while they have had little opportunity—until recently—to try ours. So, poor, I knew the taste of caviar and capers; the richest of our community's rich, however, never tasted my mother's *runzas*—bread pockets filled with sausage, beef, or pork with boiled cabbage, just the sort of thing to carry into the fields in your syrup bucket and, where possible, heat on a shovel over an open fire.

My parents prospered, and I've done all right, and so I have also sometimes experienced the view from on high. Thirty years ago, when I began my association with the Omaha, I regularly attended tribal celebrations—powwows, handgames, prayer meetings, business meetings—and quickly learned that any Omaha occasion involves food. Everyone is fed, no matter how many there are, and in fairly equal proportions, but service at an Omaha feast begins with distinguished guests, and the best of what is being offered is sure to be given to them.

For a couple of years I was considered a distinguished guest and so I was served first and I was served the best—for example, nice, even slices of pasty white bread from plastic bags, freshly purchased at the grocery store, while my Omaha friends reached into bushel baskets to grab hunks of the lower-status, nut-brown, fragrant fry bread made in their own kitchens. I looked on with lust. Finally, I asked if I could possibly skip the white bread and have some of the fry bread, a breach of etiquette so brash some Omahas threatened to give me the name "Fry Bread" when I was adopted into the tribe a few years later.

So, here's the cultural flow chart: My parents were embarrassed by the dark, heavy rye bread they carried in their lunch pails to school and dreamed of eating the white, sticky "store bread" the rich kids ate; in midgeneration I ate the white stuff, telling my mother that all I wanted for Christmas was a few loaves of that low-class rye bread she had finally succeeded in leaving economically if not culturally behind her. With Indian friends I became the boor and begged for their "peasant" bread (which derived, incidentally, from the bread made by military cooks at nineteenth-century forts on the Plains).

And now comes the commercial synthesis, America's inevitable culture-in-a-box. My Czech wife came home yesterday to our Danish town from a grocery store with an Irish name in a historically German town with an English name, having purchased a package of Indian fry bread mix, manufactured by the Woodenknife Company of Interior, South Dakota. Now we have fry bread from the box, premixed French bread from our bread machine, and Mom's latter-day rye bread in the freezer—and complaints from our twelve-year-old daughter Antonia that she's underprivileged because we never have any "store bread."

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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When Nature Writers Get It Wrong

by Jack C. Schultz

Reading these two books together makes one thing clear: ignoring rigorous science, using sources and opinions selectively, employing illogic, and invoking mysticism can permit polemicists to promote wildly different and highly personal viewpoints about the state of the environment. To Gregg Easterbrook, author of *A Moment on the Earth: The Coming Age of Environmental Optimism,* nature's garden is in the best shape ever, and anyone who thinks otherwise is a selfish, deluded alarmist. But Charles Little, in *The Dying of the Trees: The Pandemic in America's Forests,* sees disease in the forested part of the garden, and states that we are the culprits behind the epidemic. In each of eight short chapters, Little describes a "catastrophic" problem in a forest somewhere in the United States. While a few of these problems have well-documented human causes (for example, ozone damage in the Los Angeles basin), the sources of others (acid rain) are debatable or unknown (the epidemic of dogwood disease called anthracnose). Some (replacing old growth forests with younger stands; gypsy moth outbreaks) might not even be considered problems.

Little, a journalist who has worked the environmental beat for thirty years, depends heavily on the views of local observers and advocates, and on the emotional statements of a few interested scientists from diverse disciplines. Nary a refereed publication nor a balanced scientific treatment is referred to in the book's pages, despite a huge literature on many relevant topics. But then, Little is convinced that establishment science is too "beholden to industry" and too constrained by political interests to make fair-minded evaluations. This will surprise the many fine researchers funded by grants from such agencies as the National Science Foundation. A dose of rigorous, refereed science—which generally indicates that complex interactions rarely have simple, much less single, causes—would have taken the wind out of Little's exhortative sails. Although his point that forests in the United States have long been badly managed is a good one, his argument that diverse phenomena—such as gypsy moth outbreaks, dogwood anthracnose, tree dieback in Vermont and Appalachia, and forest fires in the West—can all be traced to a common cause just doesn't impress.

THE DYING OF THE TREES: THE PANDEMIC IN AMERICA'S FORESTS, by Charles E. Little. *Viking Press; $21.95; 264 pp.* A MOMENT ON THE EARTH: THE COMING AGE OF ENVIRONMENTAL OPTIMISM, by Gregg Easterbrook. *Viking, $27.95; 745 pp.*

Little repeatedly assumes that there is broad scientific agreement about the causes and effects of many environmental phenomena. In the case of global CO_2 accumulation, for example, he ignores the growing body of evidence that many of its environmental effects are likely to be positive. Eschewing such "details," Little concludes that this is the time for despair and alarmist rhetoric. He is clearly sincere, but I'm afraid that his premise is false, providing grist for Easterbrook's mill.

In a mammoth, three-part polemic, Easterbrook, a magazine journalist, looks into nature's garden and concludes that we live in the best of all possible worlds, and that it's only getting better. In Part I, he attempts to convince us that nature is nothing less than a highly resilient, mystical superorganism—even a deity—with its own "needs" and "values." Reviving some old philosophy and some bad science in support of this viewpoint, he reintroduces John Locke's version of natural law, under which human values and inalienable rights are on a par with nature's and are thus permitted to compete with them. Hence causing the extinction of a species is not only a trivial "natural" act (nature itself has caused many more) but is justifiable under natural law.

Conveniently, natural law's tenets are perceptible only to humans who believe in them, and so the concept has been used periodically to validate any number of viewpoints—minority, liberal, conservative, status quo, or revolutionary. Easterbrook upholds that tradition by condemning those who might place nature's values in conflict with those of humans. These "enviros," as Easterbrook labels them, are caricatured as ponytailed, bluejeaned, selfish misanthropes who crave solitude, adore nature, and favor population control because they hate other humans and harbor deep-seated, "fashionably correct" guilt for "having defiled the garden." Having placed environmentalists beneath contempt with that bit of psychobabble, Easterbrook proceeds to twist science and nature to his own ends.

Part I contains some of the most egregious cases of misunderstood, misstated, misinterpreted, and plainly incorrect "science" writing I've ever encountered. The abuse of the concept of natural selection here could turn Darwin in his grave, were it worthy of contemplation. In his own time, Darwin refuted Easterbrook's bastardized version of evolutionary theory, called progressivism, because it asserts that evolution constantly improves organisms according to some human standard. Seeing Easterbrook twist one of my professional specialties—plant chemistry—to show that plants need not suffer increasing ultraviolet light levels gave me something worse than sunburn. The section-ending list of "Nature's Values" had me laughing out loud. Examples: "cooperation is better than competition"; "creatures, ecologies [sic], and people get better (evolutionarily) with the passage of time"; "most changes are good for living things"; "physical objects are not as . . . important as the lowliest living creature." Easterbrook isn't even consistent from chapter to chapter. The supreme value of the "lowliest" creature goes out the window when a property value is compromised, as in efforts to protect an endangered species or any time the creature is an insect. He appears to have a severe case of entomophobia (protecting beetles is "nonsense").

In Part II, Easterbrook launches his argument that the current environmental situation not only isn't bad; it's good and getting better. Here, he reveals an appreciation for the complexity of the world's ecosystems that Little lacks. He realizes, for example, that recent studies suggest that forests will absorb more of the potential increase in atmospheric CO_2 than we'd thought. Although he provides repeated "that's no excuse for environmental abuse" disclaimers in this and other scenarios, the clear conclusion is "don't worry; be happy." Of course, our present understanding doesn't permit this conclusion—we simply don't know what will happen. What Easterbrook has done differently from Little is simply to take another turn in the incomplete maze of ecological understanding.

Throughout Part II, we are treated to ever more logical and factual wonders: the main reason acid precipitation may be a problem in the Blue Ridge Mountains is that those darn peaks are just so high that they intercept the stuff (I'd hate to see the remedy for this); the desire by enviros to limit population is "self-centered," but the desire to sacrifice endangered species for personal gain is not; the desire to preserve old-growth forest is motivated in Saab-driving "snobs" by a hatred of logging trucks; and, again, every animal on earth "may be vital to the cosmic enterprise" and should be preserved "with joy" except, apparently, for insects.

In his ignorant optimism, Easterbrook sees no difference between a monotypic tree farm and a complex, unmanaged forest, thereby concluding that if the total tree count is okay, so is the world. (This is what I call a "suburban lawn" view of the world—my lawn's enough nature for me! Perhaps that's why he seems to think that increasing human population density will have no negative consequences for the quality of life and why he acknowledges the tragedy of fifty lives lost annually to tigers by "poor unarmed people risking their lives to . . . feed their children" but not that of the hundreds or thousands of lives lost to poor, armed people in any of our crowded American cities.)

Easterbrook almost managed to get my respectful attention back on track at the start of Part III with a discussion of the underappreciated resilience of nature. But soon came signs of a final derailment in an attempt to foresee the environmental future: species will "get better" (meaning more humanlike, I suspect); predation will end as species live in "enlightened cooperation" (except for plants, which would be the big losers as all animals, not just people, go vegetarian); there will be no more extinction since "disease is a defect of nature" (just think of a world with no predators or parasites to regulate the plant eaters). As Easterbrook violated more and more natural laws (not natural law), I began looking for the joke's punch line. What I found instead was a penultimate chapter seriously proposing colonizing the

Illustrations by Yvonne Buchanan

planets. When the final paragraphs proposed inserting religious (Christian) values into environmentalism, the derailment was complete.

These are dangerous books for dangerous times; I'm sure Easterbrook's volume is near the top of many Congressional reading lists. There are some among us—mostly active scientific researchers—who can explain what we do know and draw valid, albeit limited conclusions. They are the ones who should be writing about science for the general public rather than those who would exploit ignorance to fit their own agendas. Why don't they? The usual explanation is that popularizing science costs an academic respect and credibility. Now I understand why.

Jack C. Schultz is a professor of entomology at Penn State University. He teaches and does research on forest entomology, ecology, and plant physiology.

Denial in the Fortress

by David W. Orr

Gregg Easterbrook begins *A Moment on the Earth: The Coming Age of Environmental Optimism* with a summation of what he calls "ecorealism," which is essentially his view that the war to preserve a habitable earth is all but won—or will be by the year 2000—and that those who won it ought now to be upbeat and happy. Alas, they are not. Six hundred and ninety-eight pages later, he zooms back from outer space, having greened Mars, trashed all manner of what he deems to be insufficiently optimistic thinking, and created what he calls a "new nature" on earth—one without predation, aging, violence, species extinctions, and killer asteroids. Easterbrook envisions two possible long-run scenarios for Earth: one in which an overall "human population of hundreds of billions or even trillions of souls" could be living throughout the cosmos, with Earth as "a planet-size preserve"; the other a world where "a small human contingent uses advanced knowledge to live the nonmaterialist lifestyle of ecological longing." Easterbrook advertises himself as an "ecorealist."

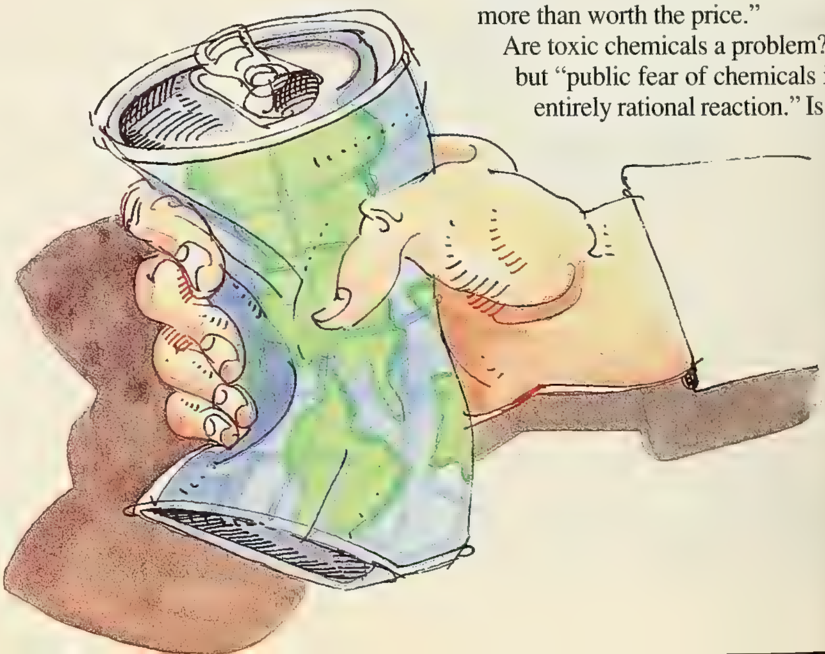
Two things happen in the book between Easterbrook's description of ecorealism and his vision of the human takeover of the cosmos. First, some 157 pages instruct us in what the author calls "the long view of Earth's environmental problems." Such things as human-induced climate change and soil erosion are portrayed as minor events; shifting continents, glaciation, and collision with asteroids have wreaked far greater havoc. "Nature," he says, "has for millions of centuries been generating worse problems than any created by people." I do not for a moment doubt the truth of this assertion. Nor do I doubt that from, say, Alpha Centauri, millions of light-years away, a nuclear war on earth would scarcely make the midday farm report. The earth is a "fortress," says Easterbrook, capable of withstanding all manner of insult and technological assault. Somehow I take little comfort.

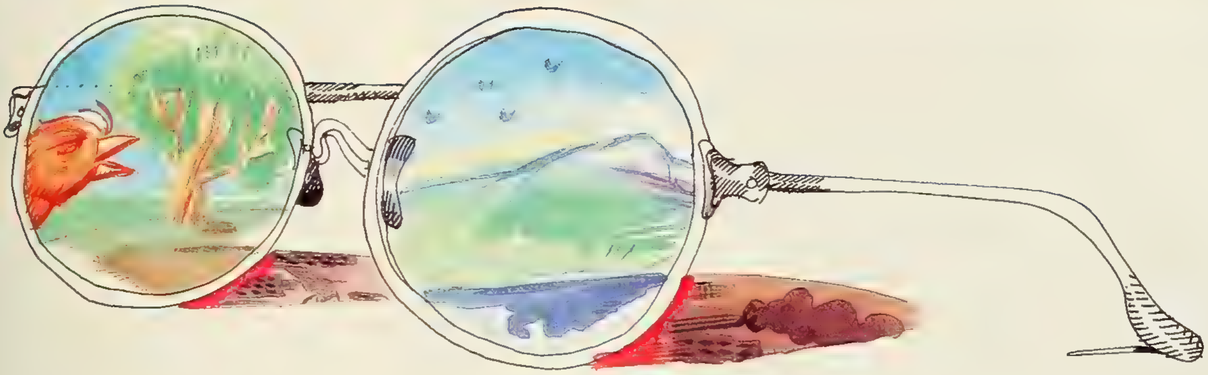
Having informed the reader that in the cosmic scheme of things, our ecological problems are not really that bad, Easterbrook then attempts to prove that they do not exist in the short-term either. In the process, we are whipsawed back and forth between environmental success stories, denial, selective use of evidence, outright error, and caveats that hedge all of Easterbrook's optimistic bets. (By the way, the Environmental Defense Fund has recently published "A Moment of Truth: Correcting the Scientific Errors in Gregg Easterbrook's *A Moment on the Earth*," edited by Leonie Haimson and Billy Goodman.)

In fact, there are really two Easterbrooks: one carefully selecting evidence to advance a view that the war for a habitable Earth has been won; the other following quickly behind to say that it may not be so. Early on, he admits that "humanity may be executing many subtle forms of damage to the biosphere, damage that . . . is not yet apparent from our short-lived perspectives." Then he proceeds to ridicule those, including Rachel Carson, who have ever taken this view seriously.

On page 111, he downplays the possibility of global warming: "When people act in ways that put extra carbon dioxide into the air, all they do is confront nature with a bit more of a substance that would have been in the air man or no." Thirty-nine pages later, he reverses himself: "By tampering with the climate, people play with exactly that aspect of nature experience suggests [is] most likely to do them in. Even if the odds of an artificially triggered climate emergency are low, prevention is amply justified." On page 301, he asserts that "warming is probably in society's interest," but fifteen pages later he advises that "any reasonable policy that reduces the odds of climate change is more than worth the price."

Are toxic chemicals a problem? No, but "public fear of chemicals is an entirely rational reaction." Is acid





rain a problem? Well, "no," but this "does not rule out [cause for] alarm." Genetic engineering? Not a problem, but "a disaster cannot be ruled out." Overpopulation? A short-term "disaster" but "over the long term . . . a boon for the natural scheme." Farmland preservation? Not necessary, but "primal nature will not last unless society adapts a general vision of land preservation." And so it goes.

Easterbrook's grand denial rests on the assumption that "the portion of Earth taken over by humanity is fantastically exaggerated" and that humans are still a small, insignificant part of an infinitely resilient biosphere. He arrives at this view, which informs all that follows, without any reference whatsoever to the sizable volume of evidence that exists about human effects on net primary productivity, ecological carrying capacity, the circulaion of materials, biotic systems, and biogeochemical cycles.

Toward those who hold alternative poitions, Easterbrook is dismissive. Although he applauds the "extraordinary uccess of modern environmental protecion . . . perhaps the best instance of govrnment-led social progress in our age," e does not like the tens of thousands of eople who brought it about, whom he alls the enviros. They "pine for bad ews." They suffer from a "primal urge to ecree a crisis" and from dubious "subonscious motives to be alone with naure." Pessimism, for them, is "stylish." He does, however, have kind things to say bout former Environmental Protection gency Director William Reilly, who in rn says exceedingly flattering things bout the book on its jacket.) Mostly, Eastbrook approves of those whose focus is urely technological and dislikes those who raise larger and messier questions about ethics, justice, and politics.

Ah yes, politics. In the fall of 1994, about the same time that Easterbrook would have been working over the galley pages for *A Moment on the Earth,* agents for the Republican Party were drafting the final version of "The Contract with America," one part of which aimed to dismantle the environmental protections so painstakingly erected over the past twenty-five years. Easterbrook and his happy book were blindsided by reality. From the rubble of collapsed illusions, he wrote in the *New York Times* on April 21 that "until the new Congress began, all signs seemed encouraging." Where has Easterbrook been? Were these signs not apparent in virtually every legislative and regulatory battle of the past twenty-five years? Now he plaintively wonders whether "all the apparent progress in the chemical industry [has] been merely a public-relations ploy" or whether he was duped by the logging industry, which "recently embraced a bill that would make a mockery of the Endangered Species Act."

Easterbrook's ecorealism rests on a foundation of political naïveté. Few environmentalists have ever doubted that we had the technical know-how to lessen human damage to the environment. The problem has always been whether we had the political will and moral energy to do so. But *A Moment on the Earth* has virtually nothing to say about human arrogance, greed, stupidity, and evil—all of those things that keep people and whole societies from doing what they can do and what they ought to do. Nor does it have anything but scorn for recent attempts to recalibrate our ethics and religious beliefs to include care for the natural world. Easterbrook, who describes himself as a liberal Presbyterian, parodies this belief system as "Earthianity."

The enviros for whom he has such scorn, the very people who brought about the "extraordinary success of modern environmental protection," are more often than not motivated by some larger vision of reality than Easterbrook wishes to acknowledge. The global movement to preserve a habitable and beautiful earth is not just fuzzy sentimentality or self-interest: it is about transcending self-interest in order to be faithful to larger duties and obligations. For many enviros, it is about the sense of wonder experienced before the mystery of creation itself. For people so motivated, the principle of caution preempts economic and technological carelessness. Easterbrook likes the results of the enviros efforts—environmental protection—but does not like the combination of moral outrage and plain good sense that have so far made it happen.

A Moment on the Earth is already out of date, but its influence will, unfortunately, linger for a long time. Yes, there have been notable environmental successes, but they mostly concerned issues that were relatively easy to deal with. Even these gains are tentative and currently under assault. The hard issues and the difficult choices are still to come. When we do finally confront these things, we will discover that they are as much involved with politics and morals as with science and technology. That being the case, it's foolish to hold the victory party quite so soon.

David W. Orr is chair of the environmental studies program at Oberlin College. He is the author of Ecological Literacy *and* Earth in Mind.

Continued from page 11

house counts as a "final cause" (final not in the temporal sense of coming last, but in the Latin meaning of a purpose).

One of the most striking differences in the nature of science between Boyle's day and our own lies in changes that have occurred in the meaning of causality. One alteration is only terminological and therefore less important. We would still acknowledge the vital character of material and formal factors, but we no longer choose to label them as "causes." As the fundamental change, the mechanical revolution unleashed by Boyle and his generation was so successful that the actual building and manipulation of things, called "efficient" causes by Aristotle, became enshrined as the only acceptable definition of causality. Meanwhile, and in consequence, the notion of purpose, or final cause, was banished from science. We no longer believe that inorganic objects have intended purposes, defined either in human or in any other terms. As for organisms, we surely allow a notion of purpose in the vernacular sense that good designs have functions (yes, eyes are really for seeing), but we now view such functions as products of the efficient cause of natural selection, and not as conscious intentions either of organisms themselves or of a creating deity.

But final causes remained orthodox (in science as well as religion) during Boyle's time, and he wrote his 1688 treatise to define the appropriate domain of final causes and to assess the evidence for their action. Interestingly, Boyle sets up the issue as a "Goldilocks" problem by identifying one class of objects as too little, another as too big, and a third as just right. In defining the good design of organisms as the "just right" category, Boyle firmly linked the venerable notion of final causes to biology and therefore rooted his natural defense of religion in the very phenomena that Darwin's revolution would later identify as a product of ordinary efficient causality. Boyle's argument—that good organic design implies benevolent purpose in the cosmos—provides a comfort and appeal that we have not been able to relinquish. So we shore up the pedestal that Darwin should have smashed, and we spin doctor our interpretation of evolution to view organic change as predictably purposeful (rather than fortuitously contingent), thereby converting Darwin's mechanism into a false argument for the same comfort that Boyle's God once provided.

Boyle begins his argument by stating that two schools of philosophical thought deny the existence of ascertainable final causes for opposite reasons: the Epicureans, who view material objects as constructed by chance, and the Cartesians, who regard God's wisdom as so inscrutable that mere earthly mortals could never discern his true purposes.

> Epicurus and most of his followers banish the consideration of the ends of things [final causes] because the world being, according to them, made by chance, no ends of anything can be supposed to have been intended. And on the contrary, Monsieur Des Cartes, and most of his followers, suppose all the ends of God in things corporeal to be so sublime, that 'twere presumption in man to think his reason can extend to discover them. So that, according to these opposite sects, 'tis either impertinent for us to seek after final causes, or presumptuous to think we may find them.

Boyle then applies his Goldilocks approach in asking what class of natural objects might display final causes indicating creation by an omniscient and loving deity. In Mama Bear's category of "too little," Boyle places the inorganic objects on our earth—"inanimate in the sublunary world," in his terminology. Rocks and waters are so simple in composition that they might either be formed by chance (and therefore subject to the Epicurean objections against final causes) or built directly by nature's constant and simple laws. (God ordained the laws, to be sure, but objects assembled by physical forces under the laws of nature, and not created by God, do not display God's purposes directly.) Boyle writes:

The bodies of animals and plants afford "clear and cogent arguments of the wisdom and design of the Author."
—*Robert Boyle*

> As for inanimate bodies, as stones, metals, etc . . . most of them are of such easy and unelaborate contextures, that it seems not absurd to think that various occursions and jostlings of the parts of the universal matter may at one time or another have produced them, since we see in some chemical sublimations and crystalizations of mineral and metalline solutions, and some other phenomena, where the motions appear not to be particularly guided and directed by an intelligent Cause, that bodies of various contextures as those are wont to be, may be produced.

In Papa Bear's category of "too much," Boyle places the massive, inorganic objects of the cosmos—our sun, the planets and the stars. They are so vast, so distant so ineffable. God must have made them but not for us (remember that the first pedestal had already been smashed). These bodies, therefore, cannot display satisfactory final causes that might comfort or enlighten human beings. Stars and planets fall prey to the Cartesian claim that God's purposes are too arcane for human understanding. The stars extol God's greatness, but not his loving kindness—and proper final causes must imply both God's existence and his benevolence: "The Cartesian way of considering the world is very proper indeed to show the greatness of God's power, but not, like the way I plead for, to manifest that of his wisdom and beneficence."

What objects shall then occupy Baby Bear's category of "just right"—"the way I plead for," in Boyle's terminology. Boyle argues that animals and plants supply the proper evidence for final causes proving God's existence and goodness. First, in contrast to Mama Bear's simplicity of inorganic objects, animals are sufficiently complex to require a direct creator:

> If we allow chance, or anything else, without the particular guidance of a wise and all-disposing cause, to make a finely shaped stone, or a metalline substance . . . there are others that require such a number and concourse of conspiring causes, and such a continued series of motions or operations, that 'tis utterly improbable, they should be produced without the superintendency of a rational agent, wise and powerful. . . . I never saw any inanimate production of nature, or, as they speak, of chance, whose contrivance was comparable to that of the meanest limb of the dispicablest animal.

Second, against Papa Bear's ineffable grandeur of stars and planets, the parts of animals are familiar enough to reveal their purposes, and therefore to show their creator's intent: "I cannot but think," Boyle writes, "that the situations of the celestial bodies do not afford by far so clear and cogent arguments of the wisdom and design of the author of the world, as do the bodies of animals and plants."

I wish that I had space to explicate Boyle's detailed and clever (but also often forced and insupportable) arguments for optimal design and utility of every part and function of organisms. Instead, I will only point out that this classic argument for God's existence and benevolence also builds the pedestal that we seem so loath to smash in order to complete Darwin's revolution—for if the biosphere is a well-oiled machine of divine construction, and if purposes should be construed in terms of utility to humans (as the most perfect of all God's creatures), then natural theology affirms our domination and right to rule. One last time, in Boyle's words:

> The terraqueous globe and its productions . . . and especially the plants and animals 'tis furnished with, do . . . appear to have been designed for the use and benefit of man, who has therefore a right to employ as many of them as he is able to subdue. . . . Therefore the kingly prophet had reason to exclaim: How manifold are thy works O Lord! How wisely hast thou made them all!

When Darwin set out, with conscious ntent to revolutionize human thought on he status and history of plants and animals, he did not deny Boyle's premise that organisms are well designed—and that excellence of anatomy and function sets the primary problem for natural history to resolve. He writes, in the preface to the *Origin of Species*, that evidence of taxonomy, embryology, paleontology, and biogeography would be sufficient to prove that evolution had occurred, but we could not be satisfied until we had explained "that perfection of structure and coadaptation which most justly excites our admiration."

But Darwin then turned Boyle and aley upside down in accepting their remise (excellence of organic design), hile inverting their explanation. Instead f a benevolent deity making organisms xpressly for higher purposes (with uman utility primarily among these intentions), Darwin postulated a mechanis- process called natural selection (an effi- ent cause). Moreover, and most sruptive of older traditions, Darwin's use does not operate on "higher" entities ch as species and ecosystems, but only organisms struggling for personal re- oductive success—and nothing else! e very features of nature that Boyle and ley had read as proofs of God's exis- nce and goodness—the excellent design organisms and the harmony of ecosys- ns—became, for Darwin, side conse-

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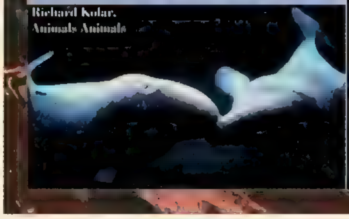

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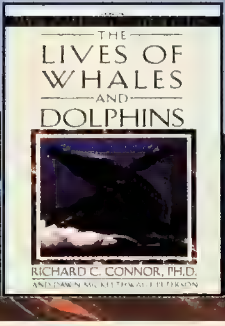

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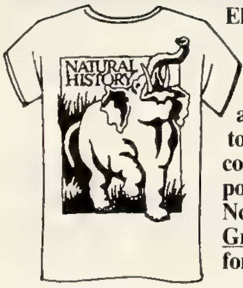

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quences of a process without overarching purpose, and working directly only for the benefit of individual organisms.

Unlike Boyle, Darwin had no abiding interest in formal theology. But we must wonder what he thought about the wider implications of evolution and natural selection for human status. In other words, how much did Darwin himself want to smash the pedestal that has prevented the completion of his revolution in Freud's sense. How far did he wish to go in undoing Boyle's traditional view of human domination (or at least superiority) in a sensibly constructed world.

Since Darwin did not write books on such philosophical questions, we must go to his private letters and notebooks. One famous letter stands out as particularly revealing (and beautifully expressed)—a proof that Darwin aspired to revolutionary status in Freud's sense. His most famous American colleague, botanist Asa Gray, had written Darwin soon after publication of the *Origin of Species*. In a heartfelt and deeply moving letter, Gray stated that he could accept natural selection as an efficient cause of evolutionary change, but that, as a convinced theist, he could not abandon the conviction (however unprovable) that God must have had some higher purpose in setting up nature to work by such a principle. Darwin, in his wonderful letter of May 22, 1860, replied with understanding for Gray's distress, but profound doubt about this traditional comfort:

> With respect to the theological view of the question. This is always painful to me. I am bewildered. I had no intention to write atheistically. But I own that I cannot see as plainly as others do, and as I should wish to do, evidence of design and beneficence on all sides of us. There seems to me too much misery in the world. I cannot persuade myself that a beneficent and omnipotent God would have designedly created the Ichneumonidae with the express intention of their feeding within the living bodies of caterpillars, or that a cat should play with mice.

Darwin then writes his key line about design and intention in the history of life—in my view, one of the greatest quotes in the annals of Western thought:

> On the other hand, I cannot anyhow be contented to view this wonderful universe, and especially the nature of man, and to conclude that everything is the result of brute force. I am inclined to look at everything as resulting from designed laws, with the details, whether good or bad, left to the working out of what we may call chance.

We now reach the crucial point in an exegesis of Darwin's view on this most fur damental of all questions. He is willing t allow lawlike predictability, perhaps eve with some underlying intent in some il defined theological sense, for backgroun generalities. But Darwin also takes pedestal-smashing position for what h calls "the details": they are left "to th working out of what we may call chance. By this careful choice of words, and by th examples he gave (as I shall discuss in moment), I am convinced that Darwi meant what we now call contingency (un predictability due to the extreme complex ity of historical sequences), rather tha chance in the dice-tossing sense. (This is crucial distinction because pure chanc precludes any explanation of particulars but contingency, while denying that pre dictions can be made with confidence a the outset, does assert the possibility of ex planation after a particular history has unfolded. Contingency is the historian's mode of knowability; pure chance denies the explication of particulars.)

"I cannot see... evidence of design and beneficence.... There seems to me too much misery in the world."
—*Charles Darwin*

We have come face to face with another Goldilocks problem. Darwin proposes a conventional realm of generalities and revolutionary domain of particulars. But which factor dominates in the history of life? Are the particulars only a few insignificant bumps and pits on a ball that rolls according to fixed laws of motion perhaps established with a purpose? Or do the particulars form mountains and gashes so high and deep that the ball's course must follow these dominating irregularities? Are the particulars in Mama Bear's little bed or on Papa Bear's king-sized mattress (sorry for the sexist implications of these categories, but I refuse to write politically correct bedtime stories—all the better to acknowledge history's often sad legacies).

Darwin's canny continuation of his argument to Gray indicates that he places the particulars in Papa Bear's camp of "too much"—that is, too many and too influential to retain the traditional comforts of predictable human domination. He sneaks up on a ruling role for contingency with a series of three examples: the first undeniable, the third more challenging, but eminently more plausible once you accept the first two.

Example one: "The lightning kills a man, whether a good one or bad one, owing to the excessively complex action of natural laws." Fine. No arguments. The event was not random. The lightning struck where it did as a result of physical principles, but no one would say that the man happened to be in this spot by design. His death is contingent and unpredictable.

Example two: If we admit contingency for deaths, why not for births as well: "A child (who may turn out an idiot) is born by the action of even more complex laws." Again, if we understood embryology bet- er, we would know (in a physical sense) why a child entered life with severe men- al handicaps. But would we ever want to rgue that a beneficent God intended such particular, and tragic, result in establish- ng sensible principles of embryonic de- elopment? This particular outcome is a ontingency without moral meaning.

Example three: the evolutionary exten- ion. Evolution is also a process of birth nd death—of species and populations his time. If individual births (the retarded hild) and deaths (the man killed by light- ing) are contingent, then why not the irth and death of species as well—for pecies are the biological individuals of eological time scales. And since *Homo apiens* is but one species among many, hy should our birth (and potential death) e any more than another contingency: And I can see no reason why a man, or her animal, may not have been aborigi- ally produced by other laws."

My high school drama teacher once ld me that the most famous stage direc- on in English occurs in act 3 scene 3 of *e Winter's Tale,* where Shakespeare rites, after Antigonus's long soliloquy: xit, pursued by a bear." Could it be that e false and harmful traditional comfort evolutionary progress and human su- emacy might exit, as Papa Bear, mus- ed by the dominating weight of contin- ncy's realm, finally brings down his allet upon the pedestal that Robert Boyle dified, William Paley enshrined, and arles Darwin deprived of meaning? ☐

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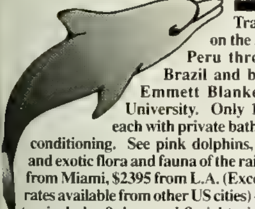

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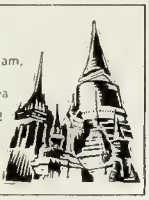

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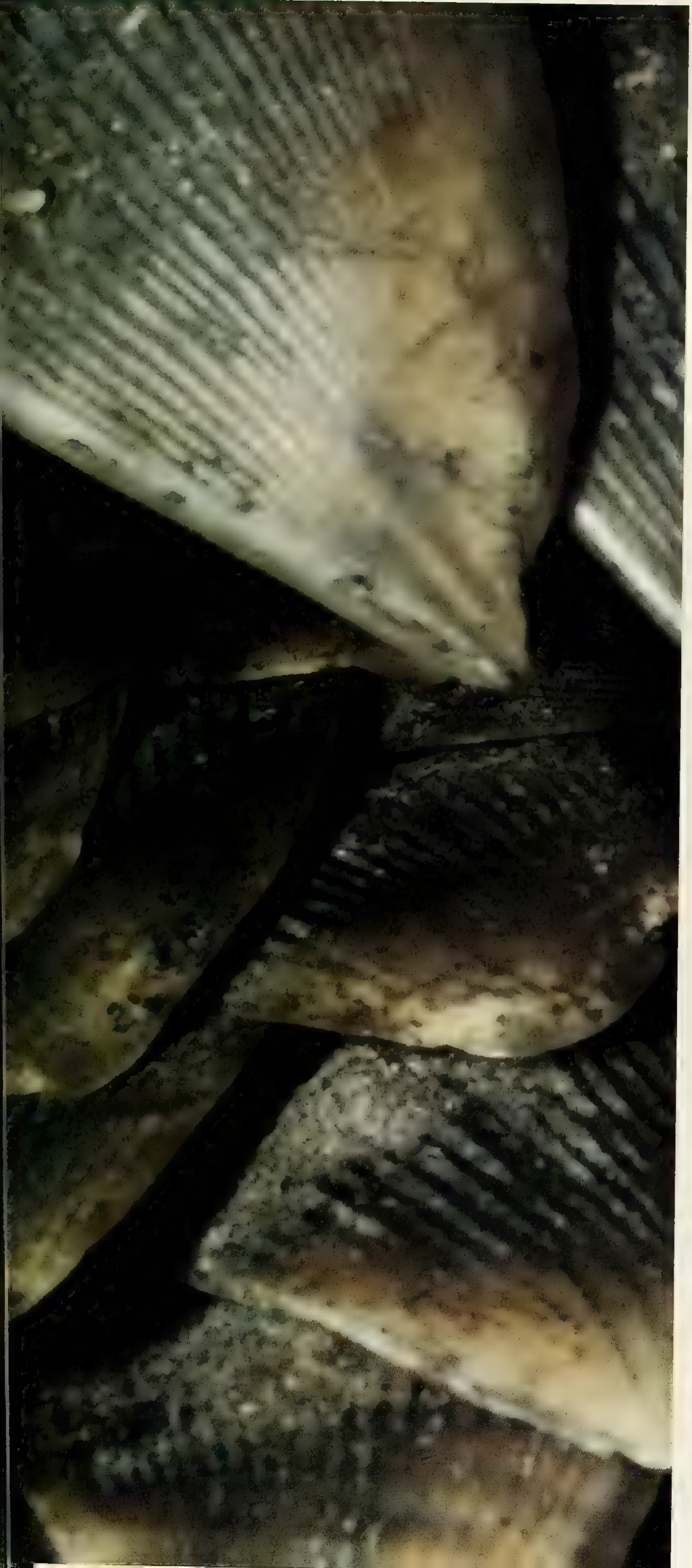

Private Eye

Peering through a chink in its armor, a curled-up Cape pangolin in South Africa's Transvaal warily regards the outside world. Its muscular tail, studded with large, triangular scales, protects its eyes and face. Once a pangolin adopts this defensive posture, even lions cannot pry it open. Pangolins also foil enemies by burrowing into the earth or climbing trees. When chased by hunters, they may curl up and roll down slopes for a quick getaway—a rare example of wheel-like locomotion in the animal world.

Seven species of pangolins are dispersed over southern China, Indochina, Indonesia, and Africa, ranging from six-pound tree dwellers to a seventy-pound West African species. Most are solitary and nocturnal; the nonarboreal species move from one temporary burrow to another. One Cape pangolin observed by mammalogist Martha Heath in Zimbabwe used as many as seventy burrows as it traveled about. Pangolins are toothless and lap up their only prey, ants and termites, with a two-foot-long tongue anchored at the pelvis. They "chew" with the abrasive walls of their stomachs, aided by the grinding of small pebbles the animal has swallowed.

Pangolin scales are much in demand throughout China for their presumed medicinal properties. The skins, too, are commercially valuable; between 1980 and 1985, 175,000 hides were imported into the United States for use in boots and shoes. Although that practice has since been outlawed, the extensive trade in pangolin products has made it one of the rarest mammals on Earth.—*Richard Milner*

Photographs by Lex Hes

AUTHORS

Lewis W. Oring (page 58) began his marathon study of spotted sandpipers in the 1970s. "While studying acoustical communication," he recalls, "I observed females that had completed clutches of eggs begin to court males. At the time, no one had documented polyandry—females taking more than one mate—in any wild bird. I decided to change my focus and pursue this fascinating life history phenomenon and did so for more than two decades." Oring is the director of the program in ecology, evolution, and conservation biology at the University of Nevada in Reno and is currently investigating the breeding biology of killdeer and American avocets and the biodiversity of wetlands in the Great Basin.

Trained as a wildlife biologist, **Irynej Skira** (page 24) saw his first Tasmanian muttonbird twenty years ago, after joining the Wildlife Division of the Tasmania Parks and Wildlife Service. While carrying out bird population studies, he became acquainted with the Aboriginal muttonbirders who harvest the birds commercially. He recently earned a doctorate for his historical study of these people. Skira's earlier research includes studying rabbits on Macquarie Island, halfway between Tasmania and the Antarctic Circle, and observing migrating muttonbirds from shipboard in the mid-Pacific.

Simon K. Bearder (page 48) followed up his 1968 bush baby fieldwork in South Africa with studies in Botswana, Zimbabwe, Malawi, Tanzania, Kenya, Uganda, and Cameroon. In 1988 he was joined by graduate student Paul Honess, who is currently completing his Ph.D. on bush babies in Tanzania. Bearder says Honess's work "proved the key to unlocking the true potential of the bush baby research" because it resulted in the discovery of previously overlooked or unknown species. Principal lecturer in anthropology and deputy head of the Department of Social Sciences at Oxford Brookes University, Bearder is also involved in conservation work.

Lex Hes (page 74), a native of Johannesburg, South Africa, developed his dual interests in wildlife and photography during his school years. In 1976, at the age of nineteen, he became a ranger at the Londolozi Game Reserve in East Transvaal. Apart from a few trips to sub-Antarctic islands to do nature photography, he remained at Londolozi for fourteen years; during that time he studied and photographed the reserve's diverse animal and plant life. In 1991, he became a full-time writer-photographer and natural history tour guide. His first book of photographs was *Leopards of Londolozi* (London: New Holland, 1991).

Naturalist-photographer **Fred Bruemmer** (page 36) usually is found pursuing animals in frigid climes, as in this photo taken with a female harp seal in the Gulf of Saint Lawrence. A Latvian who adopted Canada as his home country in 1950, the Montreal-based author has investigated the lives of narwhals, walruses, Hooker's sea lions, Cape fur seals, and hooded seals. This time, however, the indefatigable Bruemmer has opted for a change of pace—studying the mass arrival, or *arribada,* of olive ridley turtle in Costa Rica, a natural extension of his long-term interest in marine animals. "Besides," he says, "it's a nice change from Montreal and points north." Among his many books are *The Narwhal: Unicorn of the Arctic Sea,* published in 1993 by Key Porter Books.

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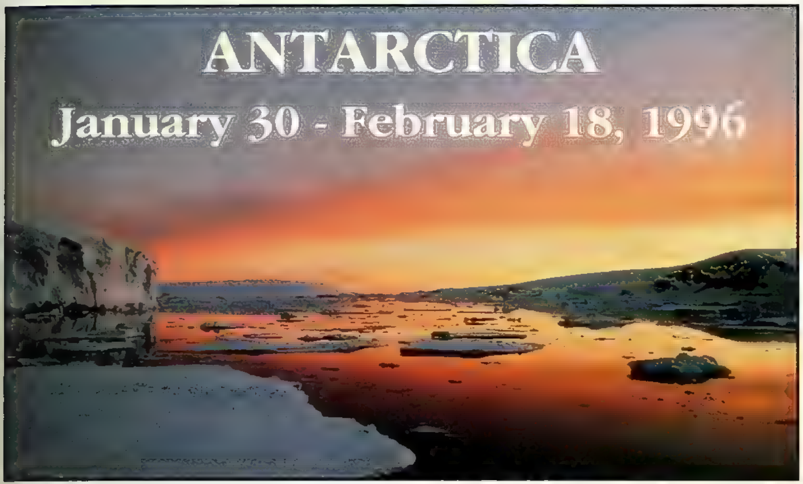

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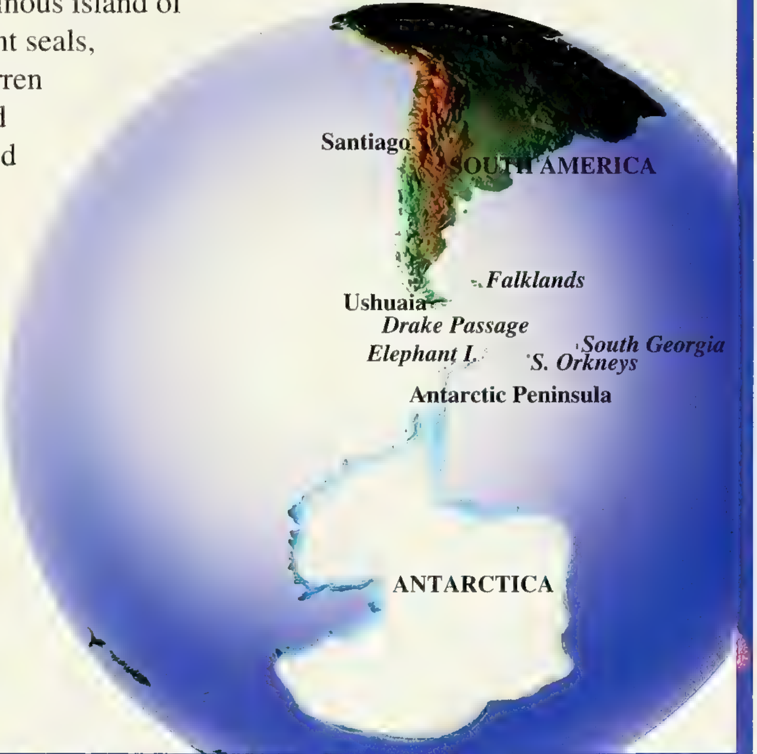

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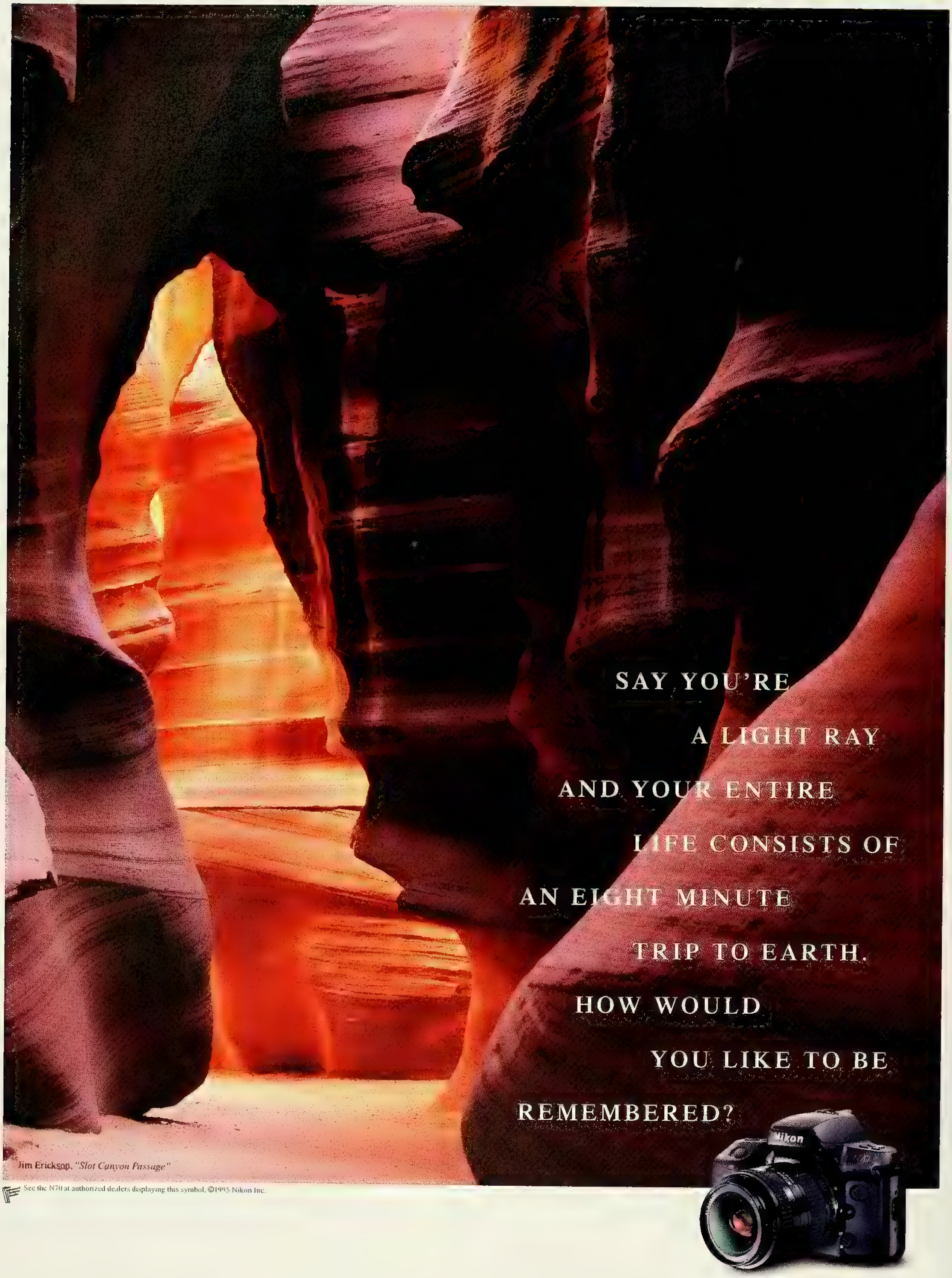
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NATURAL
HISTORY
Vol. 104, No. 9, September 1995

Up Front

At the end of June, the Supreme Court ruled that protection of habitat is a valid concern when it comes to saving endangered species. We all knew that, of course. Elementary-school science teaches that the food web ties every species to its place. But the concerns become more complicated when a species is dependent upon more than one habitat. Migrating birds breed in one place and winter in another. Along the way they must have places to feed and rest. Anadromous fishes, such as striped bass, shad, and salmon, live part of their lives in oceans and return to the rivers of their birth to spawn. The loss of only one of these habitats is sufficient to endanger a species.

Imperiled dickcissels . . .
Gianfranco Basili

Two features this month address this issue. As Gianfranco Basili and Stanley Temple tell it in "A Perilous Migration" (page 40), millions of dickcissels—as common as robins across the Great Plains of North America where they breed—converge on the llanos of Venezuela to winter in fields of sugarcane, sorghum, and rice. There, flocks of these sparrow-sized birds can darken the skies above their crowded megaroosts. Studies show that their breeding habitat in North America seems to be safe for now. But hey are being poisoned with pesticides in their winter oosts, and their population is in decline.

In "Swimming with Salmon" (page 26), writer Jessica Maxwell shows how the dwindling populations of Pacific salmon, now of such great concern to conservationists, are the products of a vast ecosystem that includes not only the dammed and damaged streams and rivers of the Northwest but also the entire Pacific Ocean itself and the atmospheric pulse that drives the circulation of its currents.

Both these articles could serve as briefs to the Supreme Court. Narrow, legal definitions of habitat ignore the lessons of natural history. You can't solve the problems of migrating birds by protecting them in one place at a time. You can't solve the plight of the salmon by shoveling hatchery fish into the rivers to replace the wild fish lost. In each case it's a matter of discovering how connected these species are to more than the one place in which we see them fly or swim. To protect these species or restore their habitats takes more than laws or money or good will—it takes getting the kind of intimate view of their lives that these stories provide: a flight with a dickcissel; a swim with a salmon.

Bruce Stutz

. . . and threatened salmon
Natalie B. Fobes

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Cover: A spawning sockeye salmon: Can the sockeye and other species survive? Story on page 26. *Photograph by Natalie Fobes; National Geographic Society*

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History on Camera

The photograph and film collections of the American Museum of Natural History contain more than one million images and three thousand reels of film. The collections include a film documenting the 1923 discovery of the first-known dinosaur eggs in Mongolia; a series of prints from 1898 of the now-extinct passenger pigeon; studio photos of a feather found in ninety-million-year-old amber; and the collection's oldest piece, a photograph of flowers taken in 1840 by American painter and natural scientist Charles Wilson Peale's sixteen-year-old granddaughter, Florida Peale.

Shortly after the Museum was chartered in 1869, Albert S. Bickmore, one of its founders, its official superintendent, and the first curator of the Department of Public Instruction, began developing a system of visual education using lantern slides projected onto a screen. These 4 × 4" black-and-white transparencies on glass plates, often hand-painted by artists, were used by teachers and lecturers until the 1930s. When Bickmore died in 1914, the lantern slide collection numbered 80,000.

The Museum's first photograph collection was acquired in 1881 from Israel Powell, superintendent of Indian Affairs in British Columbia. Powell and photographer Edward Dossetter had acquired numerous Northwest Coast Native American objects and Dossetter had taken more than 400 photographs depicting these objects in their natural environment. Bickmore selected a number of these to be enlarged and printed on glass panels that were placed over the windows lining the hall of the original Museum structure.

In 1891 the Museum hired a photographer for the first time to document one of its expeditions. Carl Lumholtz, an anthropologist, took more than 2,000 photographs of northern Mexico's indigenous peoples. Photographers have since accompanied more than 1,000 Museum expeditions, creating images ranging from daguerreotypes to motion picture footage, a unique record of the natural world.

The photograph collections are open to the public Tuesday–Friday from 11:00 A.M. to 4:00 P.M. Film collections can be viewed by appointment only.—*Joel Sweimler; Manager of Special Collections, AMNH*

SEPTEMBER EVENTS

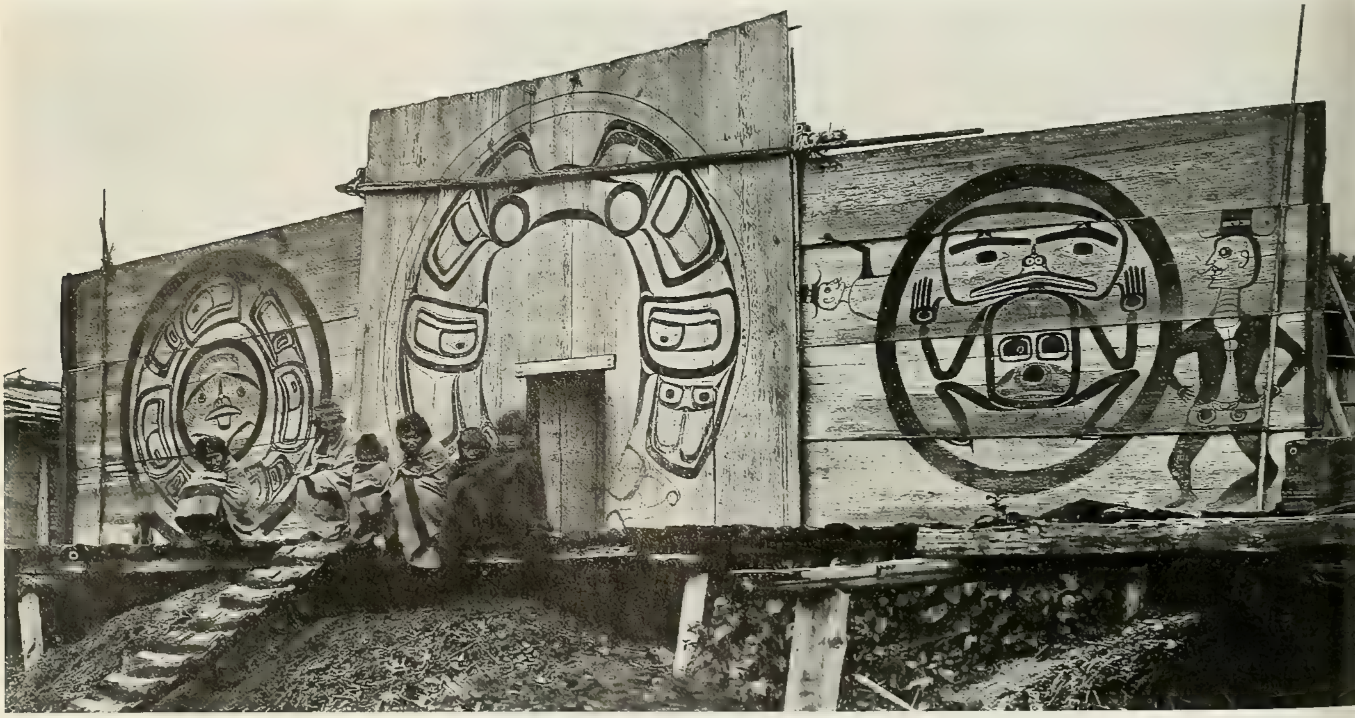
On Thursday, September 7, Virginia Morell will give a lecture based on her book *Ancestral Passions*, a biographical account of the Leakey family, at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for information.

Hayden Planetarium's new Sky Show, "Cosmic Mind Bogglers," which premières on Thursday, September 7, will present some of the universe's "cosmic record holders." Call (212) 769-5100 for details about all current Planetarium event

The Japanese ensemble Ume waka Roluru and Co. will perform works of Japan's classic No theater in the Hall of Ocea Life on Saturday, September at 1:00 P.M. Call (212) 769-531 for information about this an other free programs in the Education Department's serie "Multicultural Mosaic: Trad tions of a Diverse Society."

Scientists from the America Museum of Natural History an the Cuban Museo Nacional d Historia Natural have collabo rated on a bilingual exhibitio "Cuba: Nature of an Island, that will go on permanent dis play in Havana beginning Sep tember 17. For additional info mation, call (212) 769-5099.

The American Museum of Nat ural History is located on Cen tral Park West at 79th Street i New York City. For more info mation regarding the Museum hours and admission fees, ca (212) 769-5100.



The first photograph collection purchased by the American Museum included this view of a Bella Coola Indian house, 1881.
Edward Dossetter; AMNH

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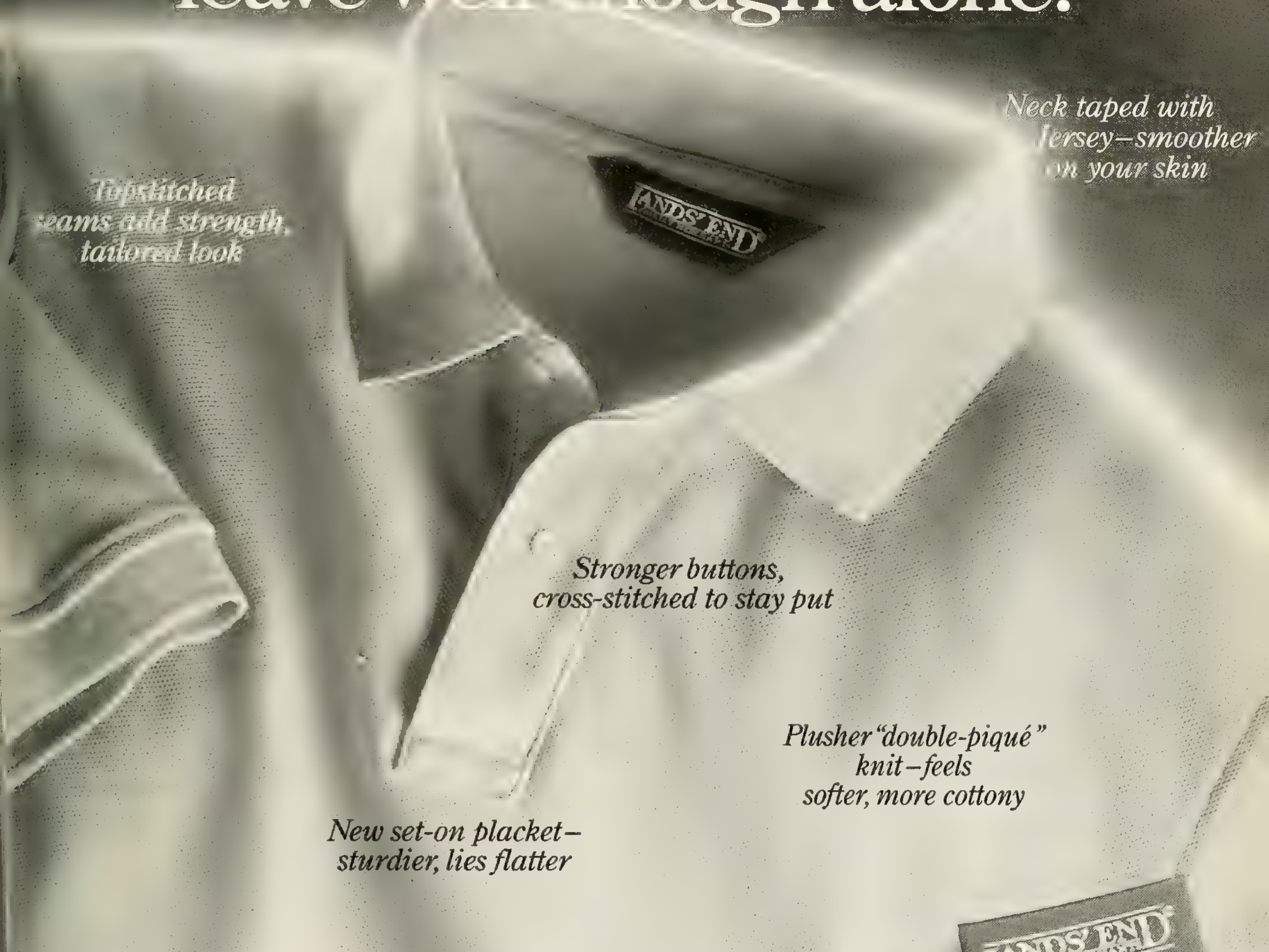

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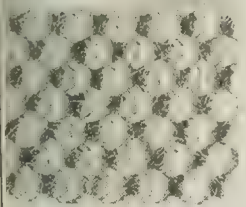

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LETTERS

Absolute Body Temperature

In his essay "Cosmic Windows" ("Universe," June 1995), Neil Tyson states that 310° absolute corresponds to room temperature. But 310° absolute is equivalent to 37° Celsius, or 98.6° Fahrenheit. Does he really keep his rooms this warm?

Angelos Zompakos
Flushing, New York

Neil de Grasse Tyson replies: No, I have never intentionally kept my rooms this warm; but my body temperature, last I checked, was 310° absolute—which is what I intended to write. Several readers noted the slip.

Who's on the Main Line?

In "Evolution by Walking" ("This View of Life," March 1995), Stephen Jay Gould celebrates the success of the fossil mammal exhibition in the new Lila Acheson Wallace Wing of the American Museum of Natural History. As Gould points out, this exhibit is organized around the mammalian family tree as determined by cladistics. Gould correctly describes cladistics as a body of theory that uses evidence of evolutionary novelty to infer genealogy. However, most of his other comments on cladistics and cladists are mistaken.

Gould assumes that in our zeal to classify mammals along "the main line" of mammalian evolution, we ignore most of what is interesting in modern biology. He asks, "What about the famous story of fewer toes and higher teeth among horses? . . . What about the loss of hind limbs in whales?"

But how more elegantly can these questions be addressed than through a detailed understanding of these animals' relationships? That in turn permits an understanding of both the order and nature of evolutionary transformation. In fact, the stories of horse toes and whale legs have been examined using cladistics and are incorporated into our new halls. The work of such researchers as Robert Evander, Bruce MacFadden, Hans Thewissen, and Annalisa Berta has not only enriched our understanding of these two evolutionary cases; it has demonstrated that these are complex issues and not just simple, linear stories of addition or subtraction.

In his March column, Gould congratulates the American Museum for abandoning linear evolutionary thinking. Yet his column is checkered with references to a "main line" of mammalian phylogeny, suggesting he hasn't abandoned such thinking himself. Furthermore, his criticisms that cladistics ignores what is interesting in evolutionary biology come too late. The main line of evolutionary biology has moved through the door of cladistics to a better understanding and appreciation for the complexity of evolutionary change.

Mark A. Norell
Department of Vertebrate Paleontology
American Museum of Natural History

Stephen Jay Gould replies: I came to praise the exhibit mounted by Mark Norell and his colleagues, not to bury it. I began with the following: "I write this essay to praise the newly opened halls of fossil mammals at the American Museum of Natural History."

Both of Norell's charges are false and disproved in my text. In his accusation, I have criticized his colleagues for "ignoring" evolutionary issues that do not easily fit into a cladistics framework. I said something quite different, and quite carefully. My article treated the gains and pitfalls of depicting evolution with a revised cladistic iconography. I pointed out that this iconography forces such phenomena as unique characters of highly derived groups into peripheral positions of the hall—not ignored, but literally marginalized. I wrote: "Such unique features and trends can only be treated in (literally) peripheral positions within the new hall of mammals—for attributes of single groups must be placed off the main line in the corners and alcoves devoted to later change within branching lines. The iconography that stirred us up now detracts from our legitimate interests by spatially marginalizing some of evolution's most fascinating phenomena."

As for references to "main lines" that supposedly "checker" my essay, the quotation cited above represents the only use of that phrase in the entire piece, and—don't you get the irony, Mark?—I am describing *your* layout of the hall. You have designed the hall (and I don't object in this case) as a main pathway with a set of branches into sides and alcoves. Cladograms have main lines and branches; this is a geometric description, not an old statement about ladders of progress. Your own diagram, which I reproduced in my essay, shows such a main pathway.

"He that troubleth his own house shall inherit the wind."

Natural History *welcomes letters from its readers. We now have an E-mail address:* nhmag@amnh.org

God and Newton

Neil de Grasse Tyson's reference to Newton in "Chaos in the Solar System" ("Universe," July 1995), fails to allow for changes in the English language since the seventeenth century. When Newton wrote "till the system wants a reformation," the "reformation" he predicted was not religious, for heaven's sake. *No* implication that God would fix things. Absurd interpretation.

Ruth Redding
Oak Bluffs, Massachusetts

Neil de Grasse Tyson replies: At the limit of Newton's brilliant discoveries was the boundary between his science and his religion. References to God in his writings tend to increase when he is less than certain of what he knows. Consider, for instance, the words immediately following the passage I quoted:

> Such a wonderful Uniformity in the Planetary System . . . can be the effect of nothing else than the Wisdom and Skill of a powerful living Agent, who being in all Places is . . . able by his Will to move the Bodies within his boundless uniform Sensorium, and thereby to form and reform the Parts of the Universe.

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The Evolved Imagination

Animals as models of their world

by Richard Dawkins

In the pioneering days of radio, my grandfather's job was to lecture to young engineers who were joining Marconi's company. To illustrate that any complex wave form can be broken down into summed simple waves of different frequencies (important in both radio and acoustics), he took wheels of different diameters and attached them with pistons to a clothesline. When the wheels went round, the clothesline was jerked up and down, causing waves of movement to snake along it. The wriggling clothesline was a model of a radio wave, giving the students a more vivid picture of wave summation than mathematical equations could ever have done.

This was my first exposure to models in the ordinary scientific sense: a model resembles the real thing in some important respects, although it may not necessarily look, to the human eye, like a replica of the real thing. A child's train set is a model, but so also is a railway timetable. Engineers build airplane models for testing in wind tunnels; weather forecasters make use of very elaborate, dynamic computer models of the earth's weather.

Biologists, too, use models to express what they think is going on inside organisms and in ecosystems. But I want to say something altogether more radical. An animal is a model. Any organism is a model of the world in which it lives. One way to understand this is to imagine a zoologist presented with the body of an animal she has never seen before. If allowed to examine and dissect the body in sufficient detail, a good zoologist should be able to reconstruct almost everything about the world in which the animal lived. To be more precise, she would be reconstructing the worlds in which the animal's ancestors lived. I say this because an animal can never be strictly adapted to its present environment. It is always adapted to a sum of past environments in which its ancestors survived. More strictly still, the sum is a weighted sum, with the weights diminishing as we go back in time.

Richard Dawkins gave the keynote address at the recent meeting of the Human Behavior and Evolution Society. Anthropologist-writer Meredith Small covered the meeting for Natural History. *See her report below.*

All these claims rest upon the Darwinian assumption that animal bodies are largely shaped by natural selection. If Darwin's theory is correct, an animal is the inheritor of attributes that enabled its ancestors to be ancestors. If they hadn't had those successful attributes, they would have been not ancestors but the childless rivals of ancestors.

So, what *are* the attributes that make for success as an ancestor, the attributes that we should expect to find in the body of our animal when we inspect it? The answer is anything that helps the individual animal to survive and reproduce in its own environment—not just one or two attributes, but hundreds, thousands of them.

This is why, if you present an animal's body, even a new species previously unknown to science, to a knowledgeable zoologist, she should be able to "read" its body

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JOURNAL

Rethinking Human Nature (Again)

The new science of sex, love, power, and status

by Meredith Small

After seven months in the Ecuadorean Amazon, University of California anthropologist Larry Sugiyama can now prove that the indigenous Shiwiar people think just like the most sophisticated capitalists. Instead of adopting the traditional approach of most ethnographers (unobtrusive observation of the culture in question), Sugiyama, a graduate student at the university's Santa Barbara campus, decided to give the Shiwiar the Wason selection task, a psychological quiz designed to determine how Western minds handle the give-and-take of social exchange.

He had two problems: the Wason questionnaire was in English, and the Shiwiar thought the whole idea of testing was pretty funny. So Sugiyama modified the test: He showed the Shiwiar photographs and told stories. "If a man lends you his boat and expects a fish in return, what happens if you borrow the boat but don't give the fish?" This they understood. A liar is a liar and a cheat is a cheat. And they knew this even without living within driving distance of a shopping mall. Deep down, Sugiyama concluded, we might all be of the same mind.

Larry Sugiyama is one of a growing group of academics called evolutionary psychologists. These scholars hold that certain universal mental principles guide our behavior—that we are, in effect,

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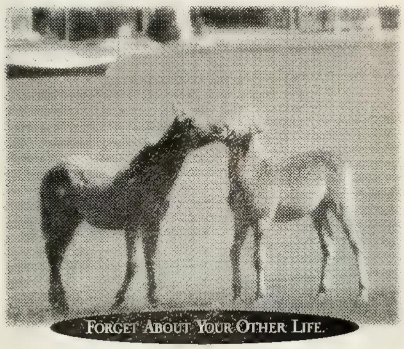

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and tell you what kind of environment it inhabited: desert, rain forest, arctic tundra, temperate woodland, or coral reef. She should also be able to tell you, by reading its teeth and its guts, what it fed on. Flat, millstone teeth indicate a herbivore; sharp, shearing teeth, a carnivore. Long intestines with complicated blind alleys indicate a herbivore; short, simple guts suggest a carnivore. By reading the animal's feet and its eyes and other sense organs, the zoologist should be able to tell how it found its food. By reading its stripes or flashes, its horns, antlers, or crests, she should be able to tell something about its social and sex life.

But zoological science has a long way to go. By reading the body of a newly discovered species, we can now come up with only a rough verdict about its probable habitat and way of life—rough in the same way as a precomputer weather forecast was rough. The zoology of the future will computerize many more measurements of the anatomy and chemistry of the animal being read. More importantly, it will not take the teeth, guts, and chemistry of the stomach separately. It will perfect techniques of combining sources of information and analyzing their interactions, resulting in inferences of enormous power. The computer, incorporating everything that is known about the body of the strange animal, will construct a model of the animal's world to rival any model of the earth's weather. This, it seems to me, is tantamount to saying that the animal, any animal, is a model of its own world or the world of its ancestors. And its genes are a coded description of the worlds in which its ancestors survived.

In a few cases, an animal's body is a model of its world in the literal sense. A stick insect lives in a world of twigs, and its body is a precise replica of a twig. A fawn's pelage is a model of the dappled pattern of sunlight filtered through trees onto the woodland floor. A peppered moth is a model of lichen on the tree bark that is the moth's world when at rest. But models, as we have seen, do not stop at replicas.

Models can be static or dynamic, and sometimes both. A railway timetable is a static model, while a weather model in a computer is dynamic: it is continually—in advanced systems continuously—being updated by new readings from around the world. (Even with the help of sophisticated computers and updated information from satellites, balloons, ships, planes, and weather stations, accurate forecasting is possible only for a few days ahead, at best.)

Some aspects of an animal's body are a static model of its world—the millstone slab of a horse's tooth, for instance. Other aspects are dynamic. Sometimes the change is slow. A Dartmoor pony grows a shaggy coat in winter and sheds it in summer. The zoologist presented with a pony's pelt can read not only the kind of place it inhabited but also the season of the year in which it was caught. Many animals of high northern latitudes,

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prewired to act in certain ways because that is how we have been molded by millions of years of evolution. Thought processes, they maintain, and the complex patterns of behavior those thoughts engender, are just as programmed into our species as are bipedalism, hairlessness, or the ability to communicate by language.

Amid a flurry of provocative magazine articles by journalist Robert Wright (cover stories on infidelity in *Time* and on feminism in *The New Republic*; a *New Yorker* feature on aggression), the field of evolutionary psychology has captured the attention of the lay public. And no wonder. So far, the field's practitioners have focused on subjects close to everyone's heart—sex, love, jealousy, anger, power, and status. Less clear is how evolutionary psychology is faring within the halls of academe. This summer, at the seventh annual meeting of the Human Behavior and Evolution Society, the evolutionary psychologists were in the limelight. But some evolutionary biology scholars are not sure what all the fuss is about.

Using evolutionary theory to understand human thought is not new. More than a century ago, when he formulated his theory of evolution by natural selection, Darwin applied it not only to anatomy but also to animal social life and human emotions. In the mid-twentieth century, European zoologists Konrad Lorenz and Niko Tinbergen took up this relatively neglected aspect of the Darwinian tradition and reapplied it to animal behavior, launching the discipline now called ethology. Then, in the 1970s, came Harvard's E. O. Wilson and the sociobiologists, who began applying a well-defined evolutionary framework to test hypotheses such as arctic foxes, snowshoe hares, and ptarmigans, are white in winter and brownish in summer.

But animals are dynamic on much faster time scales as well—time scales of seconds and fractions of seconds. These are the time scales of behavior, which can be seen as high-speed dynamic modeling of the environment. Think of a herring gull adroitly riding a sea cliff's upcurrents. It may not be flapping its wings, but this doesn't mean that its wing muscles are idle. They, along with the tail muscles, are constantly making tiny adjustments, sensitively fine-tuning the bird's flight surfaces to every nuance, every eddy, of the air around it. If we fed information about the state of all these muscles into a computer, from moment to moment the computer could in principle reconstruct every detail of the air currents through which the bird was gliding. It would assume that the bird was well designed to glide, and on that assumption construct a model of the air around the bird. Again, it would be a model in the same sense as the weather forecaster's. Both are continuously revised by new data. Both can be extrapolated to predict the future. The weather model predicts tomorrow's weather; the gull model could "advise" the bird on the anticipatory adjustments that it should make to its wing and tail muscles in order to glide on into the next second.

Even if no human programmer has yet constructed a computer model that could ad-

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about social behavior in humans and other animals. To some scholars, therefore, evolutionary psychology is not so much a new discipline as a subfield. "There is an established field of human behavior and evolutionary biology," comments Kim Hill, an anthropologist at the University of New Mexico. "And a lot of us were doing this work long before evolutionary psychology even existed."

The distinction may be merely semantic. When sociobiologists of the 1970s started suggesting that human behavior, like any other animal's behavior, had an innate component, they chose to illustrate the point by looking at such things as group hostility, aggression, sexuality, and behavioral differences between males and females. They were quickly branded as racist and sexist by those who saw their approach as a form of genetic determin-

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Reversing Established Orders

"Frogs eat flies. If flies eat frogs, then we might well be headed for bedlam or the Apocalypse."

by Stephen Jay Gould

We all know how the world works. A fisherman asks his boss in Shakespeare's *Cymbeline*: "Master, I marvel how the fishes live in the sea," and receives the evident response, "Why, as men do a-land; the great ones eat up the little ones." Consequently, when humorists invent topsy-turvy worlds, they reverse such established orders and then emphasize the rightness of their absurdity. Alice's Wonderland works on the principle of "sentence first—verdict afterwards." In Gilbert and Sullivan's town of Titipu, the tailor Ko-Ko, condemned to death by decapitation, is elevated instead to the rank of Lord High Executioner because—it is so obvious, after all—a man "cannot cut off another's head until he's cut his own off." Pish-Tush explains all this in a spirited song with rousing chorus. "And I am right, and you're right, and all is right too-loora-lay."

Social and literary critics of the so-called postmodernist movement have emphasized, in a cogent and important argument often buried in the impenetrable jargon of their discourse, that conventional support for established orders usually relies upon claims for the naturalness of "dualisms" and "hierarchies." In creating dualisms, we divide a subject into contrasting categories; in imposing hierarchy upon these dualisms, we judge one category as superior, the other as inferior. We all know the dualistic hierarchies of our social and political lives—from righteous versus infidel of centuries past to the millionaire CEO's who deserve tax cuts versus single mothers who should lose their food stamps in our astoundingly mean-spirited present. The postmodernists correctly argue that such dualisms and hierarchies represent our own constructions for political utility (often nefarious), rather than nature's factual and inevitable dictate. We may choose to parse the world in many other ways with radically different implications.

Our categorizations of nature also tend to favor dualistic hierarchies based upon domination. We often divide the world ecologically into predators and prey, or anatomically into complicated and controlling "higher" animals versus simpler and subservient "lower" forms. I do not deny the utility of such parsings in making predictions that usually work—big fish do generally eat little fish, and not vice versa. But the postmodernist critique should lead us to healthy skepticism as we scrutinize the complex and socially embedded reasons behind the original formulations of our favored categories. Dualisms based on dominance may represent, most of all, the imposition of a preferred human order upon nature, and not a lecture directed to us by the birds and bees.

Natural historians tend to avoid tendentious preaching in this philosophical mode (although I often fall victim to such temptations in these essays). Our favored style of doubting is empirical: if I wish to question your proposed generality, I will search for a counterexample in flesh and blood. Such counterexamples exist in abundance, for they form a staple in a standard genre of writing in natural history—the "wonderment of oddity" or "strange ways of the beaver" tradition. (Sorry to be so disparaging—my own ignoble dualism, I suppose. The stories are terrific. I just often yearn for more intellectual generality and less florid writing.)

Much of our fascination with "strange cases" lies in their abrogation of accepted dualisms based on dominance—the "reversing established orders" of my title. As an obvious example, and paragon of this literature, carnivorous plants have always elicited primal intrigue—and the bigger and more taxonomically "advanced" the prey, the more we feel the weirdness. We yawn when a Venus' flytrap ensnares a mosquito, but experience a *frisson* of substantial discomfort when a large pitcher plant devours a bird or a rodent.

I keep a file marked "reversals" to house such cases. I have long been on the lookout for optimal examples, where all three of the most prominent dualisms based on dominance suffer reversal: predator and prey, high and low, large and small—in other words, where a creature from a category usually ranked as small in stature, primitive in design, and subject to predation eats another animal from a category generally viewed as bigger, anatomically superior, and rapacious. I now have four intriguing examples, more than enough for a column. Since we postmodernists abjure hierarchical ranking, I will simply present my examples in the nonjudgmental chronological order of their publication.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University. He is also Frederick P. Rose Honorary Curator in Invertebrates at the American Museum of Natural History.

One of 17 stages involved in producing the new edition from Audubon's original plates for The Birds of America.

The first opportunity to acquire prints direct from John James Audubon's own plates since 1838.

In the Ornithology Department of the American Museum of Natural History, there is one room which is only open by special arrangement.

It is called the Audubon Hall.

Among the display of Audubon's watercolors, prints, drawings, guns and buckskins, nothing is more treasured than the artist's copper plates that hang on the walls.

To mark Audubon's bicentennial, the Museum decided to issue a new edition of six prints struck from these original double-elephant sized plates, last used in the early 19th century.

The first new edition since the 1830s.

The six prints in the new edition are: *the Wild Turkey, Male; the Female Turkey and Young; the Snowy Owl; the Mallard Duck; the Canada Goose; and the Great White Heron.*

To carry out this commission, the Museum began looking for a firm which retained the old 19th century skills of copper plate printing and coloring.

After a long search a firm was selected, Alecto Historical Editions of London.

An edition which is closer to Audubon's intentions.

What may surprise many who appreciate Audubon's work is that the artist, although delighted with the superb quality of the original engravings, was terribly disappointed with the coloring of many of the prints.

Indeed in one of Audubon's letters, he writes to his printer Robert Havell;

"These recent proofs are no more like my drawings than a chimney sweep is to your beautiful wife."

The Museum and Alecto therefore went back to Audubon's original watercolors, notes, letters and even bird specimens to produce this edition.

The results have not only surpassed our expectations but have also met with outstanding recognition among curators, art historians and Audubon experts.

The well known British naturalist Sir David Attenborough wrote; *"These new impressions of the 150-year-old plates could well be judged to be a finer representation of Audubon's intentions than any produced during the artist's lifetime."*

'Living Bird Quarterly', a scholarly journal published by Cornell University commented; *"Many experts are judging the new edition to be superior to Havell's original prints."*

A very limited edition.

Because of the extremely high value of the original plates and the possibility of stress to them, the Museum is limiting the edition to just 125 sets worldwide.

The plates will then be retired for at least half a century.

The set of six prints cost $50,000. (A complete 4 volume 19th century set fetched $3.7m at auction at Christie's in 1992.)

Already most of the edition has been claimed, the majority of the sets going to important collections in North America including the Library of Congress, the Boston Public Library, the McIlhenny Collection and the National Library of Canada.

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FROGS AND FLIES. Frogs eat flies. If flies eat frogs, then we might well be headed for bedlam or the Apocalypse. My colleague Tom Eisner, of Cornell University, is revered throughout our profession as the past master of natural oddities with important and practical general messages. One day in August 1982, at a small pond in Arizona, Eisner and several colleagues noted thousands of spadefoot toads, congregating on the muddy shore as they emerged to adulthood in near synchrony from their tadpole stage. Eisner and his colleagues described their discovery in a technical publication (R. Jackman, S. Nowicki, D. J. Aneshansley, and T. Eisner, in *Science,* November 4, 1983):

> Spaced only centimeters apart in places, they were all of minimal adult size (body length, 1.5 to 2 cm [less than an inch]). Conspicuous among them were toads that were dead or dying, apparently having been seized by a predator in the mud and drawn partly into the substrate, until only their head, or head and trunk, projected above ground. We counted dozens of such semisubmerged toads.

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Vint Lawrence

They then dug deeper and, to their great surprise, found that the predator was "a large grublike insect larva, subsequently identified as that of the horsefly *Tabanus punctifer.*" In other words, flies can eat toads! (Although astonishment may be lessened in noting that the enormous fly larvae are bigger than the tiny toads.) Unusually large insects and maximally small vertebrates have also been featured in the few other recorded cases of such reversals—frogs, small birds, even a mouse consumed by praying mantises, for example.

The fly larvae force themselves into the mud, rear end first, until their front end, bearing the mouthparts, lies flush with the surface. The larvae then catch toads by hooking their pointed mandibles into the hind legs or belly, and then dragging the toad part way into the mud. The larvae—please remember that many tales in natural history are not pleasant by human standards—then suck the toad dry (and dead) by ingesting blood and body fluids only.

I loved the wry last sentence of their paper—unusual in style for a technical article, but odd stories have always permitted stylistic license:

> The case we report is a reversal of the usual toad-eats-fly paradigm, although . . . the paradigm may also prevail in its conventional form. Adult *Scaphiopus* [the spadefoot toad] might well on occasions have predatory access to the very *Tabanus* flies that as larvae preyed upon their conspecifics.

J. Greenberg, reporting for *Science News* (November 5, 1983), began his commentary with the emotional impact of such reversals:

> This is the Okeechobee Fla. Little League team thrashing the New York Yankees; this is Wally Cox beating out Burt Reynolds for the girl; this is Grenada invading the United States. "This is unlike anything I've ever seen," says Thomas Eisner.

LOBSTERS AND SNAILS. Decapod crustaceans (lobsters, crabs, shrimp) eat snails, as all naturalists know. The classic case of an extended evolutionary "arms race," elegantly documented over many years by my colleague Geerat Vermeij, involved increased strength of crab claws correlated with ever more efficient protective devices (spines, ribs, thick and wavier shells) in snails over geological time. Land crabs are the overwhelmingly predominant predator of my own favorite subject for research, the Caribbean land snail *Cerion.* If snails eat decapods, we might as well retire.

Amos Barkai and Christopher McQuaid studied rock lobsters and whelks (snails of middling size) in waters around two islands, Marcus and Malgas, located just four miles apart in the Saldanhabaai area of South Africa ("Predator-Prey Role Reversal in a Marine Benthic Ecosystem," *Science,* October 7, 1988). On Malgas Island, as all God-fearing folk would only rightly suspect, rock lobsters eat mollusks, mostly mussels, and several species of whelks. Barkai and McQuaid write: "The rock lobsters usually attacked the whelks by chipping away the shell margin with their mouthparts."

The local lobstermen report that twenty years ago rock lobsters were equally common on both islands. But for unclear reasons, perhaps linked to a period of low oxygen in surrounding waters during the 1970s, lobsters then disappeared from Marcus Island. In the absence of lobsters as the usual top predator, extensive mussel beds have become established, and the population density of whelks has soared. Barkai and McQuaid asked themselves: "Why do rock lobsters not recolonize Marcus Island despite the high availability of food?"

In an attempt to answer their own question, Barkai and McQuaid performed the obvious experiment—and made an astonishing discovery: the food has become the feeder—this time by overwhelming in number, not equating in size (the whelks are much smaller than the lobsters). The conventional passive voice of scientific prose does not convey excitement well, but a good story easily transcends such a minor limitation. So, without any further commentary from me (I would only be tempted to make some arch and utterly inappropriate statement about slave revolts—Spartacus and all that), here are Barkai and McQuaid's words:

> One thousand rock lobsters from Malgas Island were tagged and transferred to Marcus Island. . . . The result was immediate. The apparently healthy rock lobsters were quickly overwhelmed by large numbers of whelks. Several hundreds were observed being attacked immediately after release and a week later no live rock lobsters could be found at Marcus Island. . . . The rock lobsters escaped temporarily by swimming, but each contact with the substratum resulted in several more whelks attaching themselves until weight of numbers prevented escape. On average each rock lobster was killed within fifteen minutes by more than 300 *Burnupena* [whelks] that removed all the flesh in less than an hour.

Sic semper tyrannis.

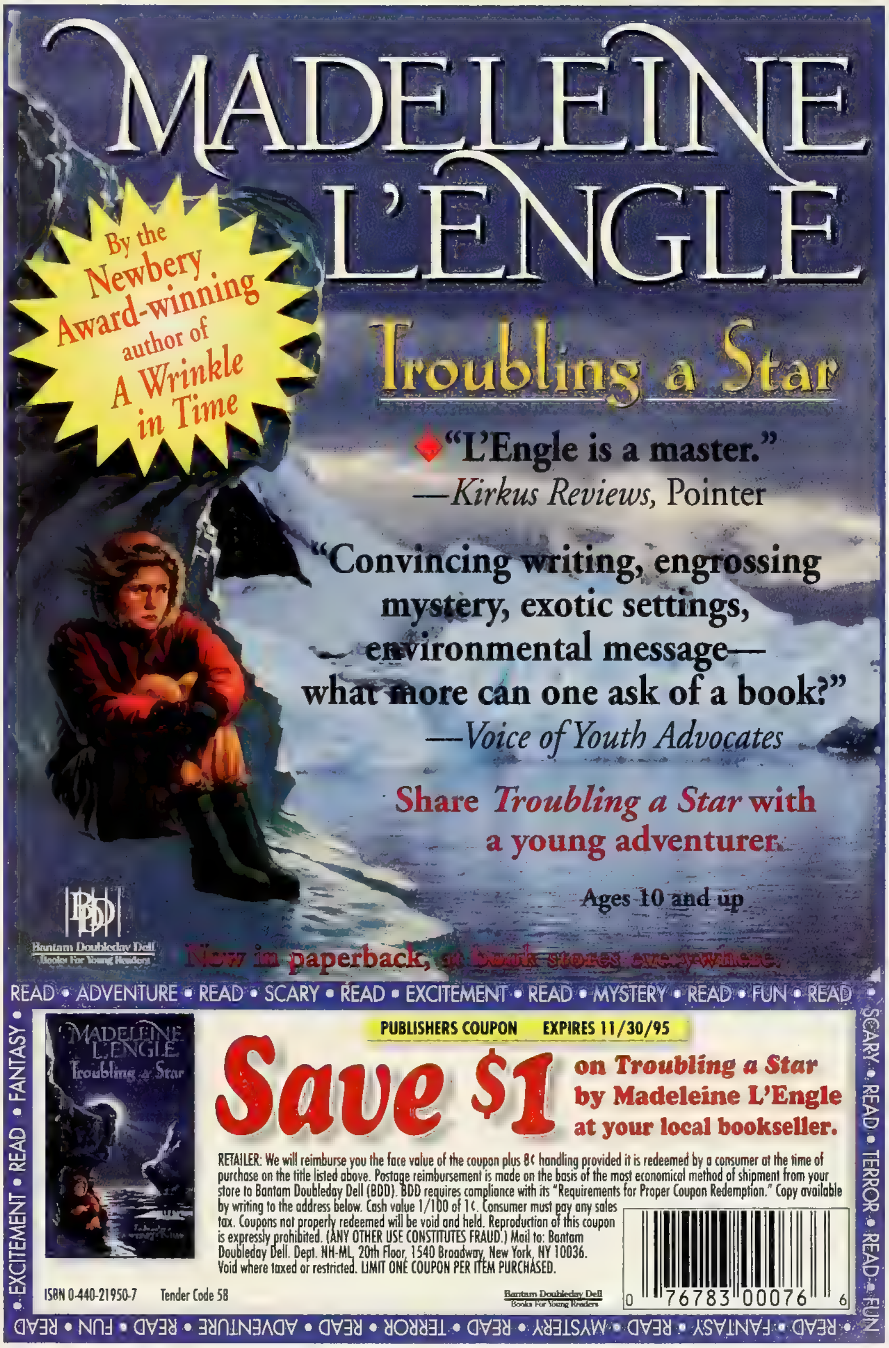
FISH AND DINOFLAGELLATES. Fish don't generally eat dinoflagellates; why should they even deign to notice such microscopic algae, floating in the plankton. And dinoflagellates certainly don't eat fish; the very notion, given the disparity in sizes, is ludicrous to the point of incomprehensibility.

Dinoflagellates do, however, kill fish, by indirect mechanisms long known and well studied for their immense practical significance. Under favorable conditions, dinoflagellate populations can soar to 60 million organisms per liter of water. These so-called blooms can discolor and poison the waters—"red tide" is the most familiar example—leading to massive deaths of fish and other marine organisms.

J. M. Burkholder and a group of her colleagues from North Carolina State University have studied toxic blooms associated with fish kills in estuaries of the southeastern United States (J. M. Burkholder, E. J. Noga, C. H. Hobbs, and H. B. Glasgow, Jr., "New 'Phantom' Dinoflagellate Is the Causative Agent of Major Estuarine Fish Kills," *Nature*, July 30, 1992). The largest event resulted in the death of nearly one million Atlantic menhaden in he estuary of North Carolina's Pamlico River.

The oddity of this case lies not in the killing of fish per se, a common consequence of dinoflagellate blooms. We have always regarded the death of fish and other marine organisms during red tides as passive and "unintended" results of dinoflagellate toxins or other consequences of massive algal populations during blooms. No one had supposed that dinoflagellates might actively kill fish as an evolved response for their own explicit advantage, including a potential nutritional benefit for the algal cells. And yet the dinoflagellates do seem to be killing and eating fish in a manner suggesting active evolution for this most peculiar reversal.

The dinoflagellate lives in a dormant state, lying on the sea floor within a protective cyst. When live fish approach, the cyst breaks and releases a mobile cell that swims, grows, and secretes a powerful, water-soluble neurotoxin, killing the fish. So far, so what?—although apparent inducement to activity (breaking of the cyst) by the presence of fish seems to suggest a direct link. The main evidence for active evolution in predation on fish is both anatomical and behavioral. The swimming cell, breaking out from the cyst, grows a projection, called a peduncle,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from its lower surface. The cells seem to move actively toward dead or dying fish. Flecks of tissue, sloughed off from the fish, then attach to the peduncle and get digested. The authors write:

> The lethal agent is an excreted neurotoxin. . . . [It] induces neurotoxic signs by fish including sudden sporadic movement, disorientation, lethargy and apparent suffocation followed by death. The alga has not been observed to attack fish directly. It rapidly increases its swimming velocity to reach flecks of sloughed tissue from dying fish, however, using its peduncle to attach to and digest the tissue debris.

SPONGES AND ARTHROPODS. Among invertebrates, sponges are lowest of the low (the bottom rung of any evolutionary ladder), while arthropods are highest of the high (just a little lower than the angels, that is, just before vertebrates on a linear list of rising complexity). Sponges have no discrete organs; they feed by filtering out tiny items of food from water pumped through channels in their body. Arthropods grow eyes, limbs, brains, and digestive systems; many live as active carnivores. Most arthropods wouldn't take much notice of a lowly sponge, but we can scarcely imagine how or why a sponge might subdue and ingest an arthropod.

However, in a crisply titled article published early this year, "Carnivorous Sponges" (*Nature,* January 26, 1995), J. Vacelet and N. Boury-Esnault, of the Centre d'Océanologie of Marseille, have found a killer sponge (about as bizarre as a fish-eating dinoflagellate—but both exist). Relatives of this sponge, members of the genus *Asbestopluma,* have only been known from very deep waters (including the all-time record for sponges of more than 25,000 feet), where behavior and food preferences could not be observed. But Vacelet and Boury-Esnault found a new species in a shallow-water Mediterranean cave (less than 100 feet), where Scuba divers can watch directly.

The deep sea is a nutritional desert, and many organisms from this habitat develop special adaptations for procuring large and rare items (while relatives from shallow waters may pursue a plethora of smaller prey). *Asbestopluma* has lost both filtering channels through the body and the specialized cells (called choanocytes) that pump the water through. So how does this deep-water sponge feed?

The new species grows long filaments extending from the upper end of the body. The surface of the filaments is covered by a blanket of tiny spicules, or small skeletal projections. The authors comment: "The spicule cover . . . gives the filaments a 'Velcro'-like adhesiveness"—the key to its feeding reversal at maximal anatomical distance for invertebrates. The sponge captures small crustaceans on the filaments—and they can't escape any better than a fuzz ball can detach itself from the Velcro strip that closes your coat pocket. The authors continue: "New, thin filaments grew over the prey, which was completely enveloped after one day and digested within a few days." The sponge, in other words, has become a carnivore.

These four wonderful stories give us pause about our dualistic taxonomies based on the domination of one category over another. The little guys sometimes turn tables and prevail—often enough, perhaps, to call the categories themselves into question.

I see another message in these reversals—a consequence of the reassessment that must always proceed when established orders crumble or merely lose their claim to invariance. In our struggle to understand the history of life, we must learn where to place the boundary between contingent and unpredictable events that occur but once in detailed glory, and the more repeatable, lawlike phenomena that may pervade life's history as generalities. (In my own view of life, the domain of contingency is vastly larger than all Western tradition, and most psychological hope, would allow. Fortuity pervades the origin of any particular species or lineage. *Homo sapiens* is a contingent twig, not a predictable result of ineluctably rising complexity during evolution.)

The domain of lawlike generality includes broad phenomena not specific to the history of particular lineages. The ecological structure of communities should provide a promising searching ground, for some principles of structural organization must transcend whatever particular organisms happen to occupy a given role at any moment. I imagine, for example, that all balanced ecosystems must sustain more biomass as prey than as predators (the basis of the so-called ecological pyramid)—and I would accept such statements as predictable generalities despite my love for contingency. I would also have been willing to embrace the invariance of other rules for sensible repetition—that single-celled creatures don't kill and eat large, multicellular organisms, for example. But our four cases of reversed order give me pause.

In a famous passage from *Origin of Species,* Charles Darwin extolled the invariance of certain ecological patterns by using observed repetition in independent colonizations to argue against a range of contingently unpredictable outcomes:

> When we look at the plants and bushes clothing an entangled bank, we are tempted to attribute their proportional numbers and kinds to what we call chance. But how false a view is this! Every one has heard that when an American forest is cut down, a very different vegetation springs up, but it has been observed that the trees now growing on the ancient Indian mounds, in the Southern United States, display the same beautiful diversity and proportion of kinds as in the surrounding virgin forests. What a struggle between the several kinds of trees must here have gone on during long centuries, each annually scattering its seeds by the thousand; what war between insect and insect—between insects, snails, and other animals with birds and beasts of prey—all striving to increase, and all feeding on each other or on the trees or their seeds and seedlings, or on the other plants which first clothed the ground and thus checked the growth of the trees! Throw up a handful of feathers, and all must fall to the ground according to definite laws; but how simple is this problem compared to the action and reaction of the innumerable plants and animals which have determined, in the course of centuries, the proportional numbers and kinds of trees now growing on the old Indian ruins!

But the same patterns do not always recur from adjacent starting points colonized by the same set of species. Even the most apparently predictable patterns of supposedly established orders may fail. Remove the lobsters from waters around one South African island, and a new equilibrium may quickly emerge—one that actively excludes lobsters by converting their former prey into a ganging posse of predators!

Thus, I sense a challenge in these four cases deeper than the raw peculiarity of their phenomenology—and the resultant attack upon our dualistic and hierarchical categories. We do not yet know the rules of composition for ecosystems. We do not even know if rules exist in the usual sense. I am tempted, therefore, to close with the famous words that D'Arcy Thompson wrote to signify our ignorance of the microscopic world (*On Growth and Form*). We are not quite so uninformed about the rules of composition for ecosystems, but what a stark challenge and what an inspiration to go forth: "We have come to the edge of a world of which we have no experience, and where all our preconceptions must be recast." □

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Star Magic

by Neil de Grasse Tyson

Twinkle, twinkle, little star,
How I wonder what you are,
Up above the world so high,
Like a diamond in the sky!

If stars did not twinkle, then the above rhyme by Jane Taylor (1783–1824) would not have been written and the world's astronomers would be very, very happy. Twinkling stars are an active ingredient in both romantic nights and bad data.

After a swift, yet peaceful journey of tens, hundreds, or thousands of light-years, the sharp pinpoint of light from a distant star reaches Earth's lower atmosphere (the troposphere), where it gets jiggled and wiggled and smeared into an oversized blob on the detector attached to a telescope. Depending on the air turbulence, some nights are worse than others. With characteristic eloquence, Sir Isaac Newton, in his 1704 treatise on optics, worried about how twinkling stars might confound astronomers of the future:

> If the Theory of making Telescopes could at length be fully brought into Practice, yet there would be certain Bounds beyond which Telescopes could not perform. For the Air through which we look upon the Stars, is in a perpetual Tremor; as may be seen by the . . . twinkling of the fix'd Stars.

He went on to suggest that a mountain might be a good place to put a telescope:

> The only Remedy is a most serene and quiet Air, such as may perhaps be found on the tops of the highest Mountains above the Grosser Clouds.

Newton was right. The sky is, indeed, more serene when viewed from mountaintops, and I agree with him that clouds are gross. But the atmosphere above mountains does not always cooperate. If you seek high-resolution images of your star field or galaxy when the twinkling is bad, then there are two obvious things to do. Plan A: close the telescope dome and go to bed. Plan B: raise $2 billion, build a telescope, launch it into orbit above the disturbing atmospheric layers, and observe the universe from there. Plan B is actually in progress in the form of the well-publicized Hubble space telescope, which now observes the universe with a leap in resolution from ground-based telescopes that is as impressive as the leap to Galileo's telescope from the unaided eye.

But there now exists a clever, less obvious remedy that is revolutionizing ground-based astronomy: adaptive optics. In some versions, lasers are used to continually monitor the blobbiness of stars. An intricate network of software and hardware corrects for the atmospheric turbulence of the moment. Fifteen years ago, this technology would have been indistinguishable from magic. Today, it produces images that, in some cases, are almost as good as what can be obtained from outside the atmosphere.

The list of cosmic objects that can be studied with the help of twinkle-free, high-resolution images is a long one. My favorites: double- and multiple-star systems, which, along with planets, can now be more readily identified in our galaxy; interstellar clouds, whose structure can be more precisely revealed, especially in sites where the detailed mechanisms of star formation are poorly understood; galaxies, which have eluded physically meaningful classification to this day, and which can now be described with unprecedented precision; the cores of dense star clusters, always busy places, which can be probed to study the evolution of rare stars that have collided and coalesced; and the nuclei of galaxies, the likely home of supermassive black holes, which can be searched for groups of soon-to-be-dined-upon stars close-by.

What actually happens when a star twinkles? Through fine optical devices, such as telescopes and eyeballs, the atmosphere looks like a tapestry of individual "patches" of air that drift across the field of view. Unfortunately, different patches have slightly different temperatures and densities, and thus different optical properties. From one patch, a light wave can be broken apart, with its segments sent on slightly different paths. The scene resembles a pond in which ripples move across an untidy ridge of stones—the smooth shape of each ripple is disturbed before reaching the shore. Under the influence of the atmosphere, a star's image will not only drift to-and-fro, but will also change its brightness from one moment to the next. Your eyes will record a twinkling star. A time-lapse photograph will record a smeared, circular blob. In fully turbulent air, the patches are especially small, the light waves are wildly dissected, and the star twinkles ferociously.

As you increase the size of an optical device, its ability to produce a sharp image will improve only until the main mirror (or lens) is about the size of the average atmospheric patch. A typical patch at the sea-level town of No Place Special is rarely bigger than four inches. In other words, if you want to overcome the twinkling problem, the largest telescope in the world will be no more effective at sea level than an amateur telescope with a four-inch-diameter mirror. From the summit of Crystal Clear Mountain, however, patches of clear air can be as large as ten or twenty inches.

So why do astronomers build telescopes with diameters of more than twenty inches? No, it is not mirror envy. A telescope's job description includes collecting as much light as possible and focusing it into a single image. The biggest visible-light telescopes, which are hundreds of inches across, allow us to detect some of the dimmest objects in the universe. And we would all agree that a detected undulating blob is better than an undetected undulating blob.

What we really want now is a clever way to take the starlight that is broken apart as it traverses different patches of the atmosphere and reassemble the segmented

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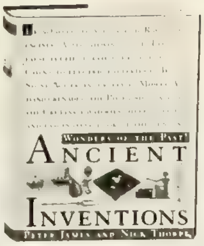
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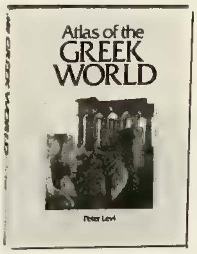
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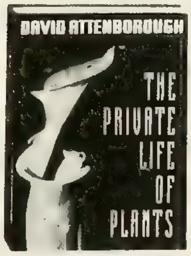
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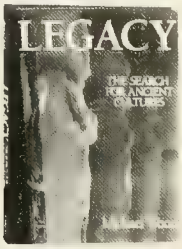
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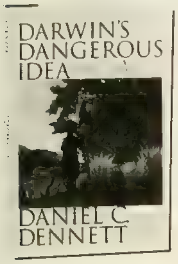
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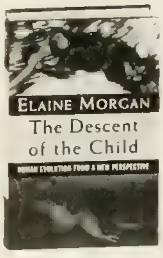
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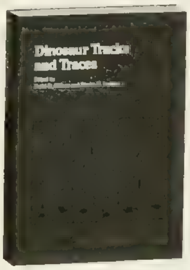
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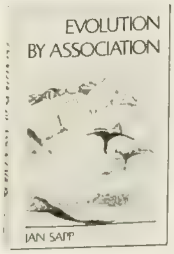
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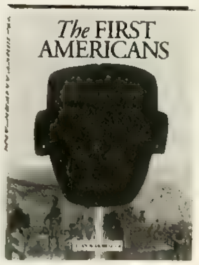
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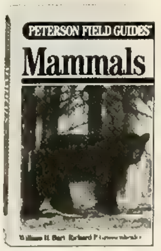
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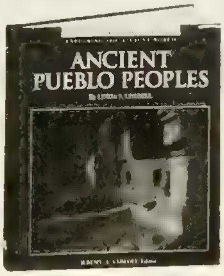
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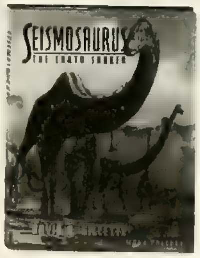
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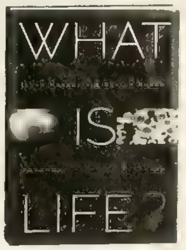
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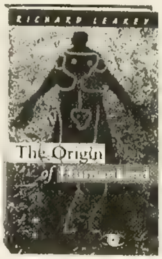
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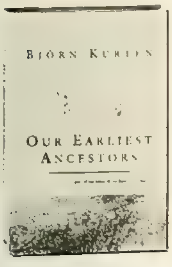
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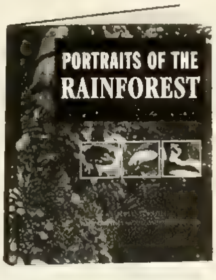
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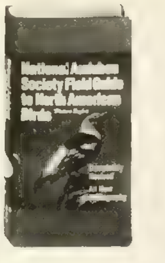
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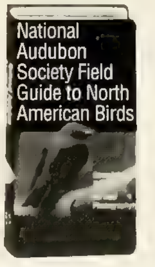
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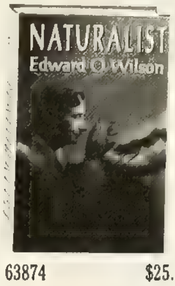
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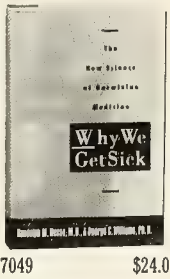
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mess into a smooth light wave, like our pristine pond ripple. To do this, we need a way to monitor every patch of sky that is seen by the main mirror of a telescope. For example, a five-meter (200-inch) telescope on a mountaintop may be able to see 100 or more atmospheric patches, so all we need to do is break the mirror into 100 parts and allow each piece to create an image that we can properly recombine.

Simple enough. But each mirror segment must monitor the light hundreds of times per second. In each snapshot, sufficient light must be recorded to simultaneously track and correct for ongoing atmospheric changes, so the only stars that can be viewed with this method are the bright ones. Ideally, one of these handy guide stars would be included in the intended field of view—near enough to the target object to be influenced by the same patch of atmosphere at the same time. But only about one-tenth of one percent of the sky is near enough to any one of these bright stars to conduct a successful adaptive optics program. Astronomers have recognized this and other practical limitations of adaptive optics systems since the first ideas percolated in the 1950s.

Astronomers strive to overcome the atmosphere's distortion of star images. To Vincent van Gogh, the twinkling of stars was an inspiration.

The Starry Night, by Vincent van Gogh; the Museum of Modern Art, New York, Lillian P. Bliss bequest. Photograph © 1994 by MOMA.

Adaptive optics remained a shelved dream until 1985, when two French astronomers, Renaud Foy and Antoine Labeyrie, suggested that an artificial "laser star" could be created high in the atmosphere, above the turbulent layers, and positioned wherever it was needed. But the technology was expensive and advances were slow. Unbeknownst to astronomers, however, in the early 1980s, the military was working on a laser-guided adaptive optics system of its own.

In the post-cold-war era, when adaptive optics research was declassified, astronomers learned that the Air Force, the Office of Naval Research, and the Strategic Defense Initiative Organization had funded successful laser-guided adaptive optics systems. The ideas and technology, now open to all, were immediately adapted by astronomers for use in the next generation of telescopes. For example, a properly tuned laser beam can now be scattered off air molecules in the stratosphere (ten miles up) to create a bright, fake guide star. Another system, still in design, feeds laser light to a fortuitous layer of sodium atoms in the mesosphere (sixty miles up), which, in turn, emits light with the characteristic yellow glow of low-pressure, sodium-vapor street lamps.

Now that we can create a fake star wherever and whenever we please, we must, as promised, create sharpened stellar images. Equipped with the light of a fake star, adaptive optics systems depend on a complicated assortment of hardware that typically includes beam splitters, interferometers, reimaging optics, and monitoring cameras. At the core of adaptive optics systems, however, is a deformable, or segmented, mirror, in which each part (sized to match a typical atmospheric patch) is controlled independently by computer-instructed "pistons" that push or pull the mirror in a manner that cancels the patch-to-patch atmospheric variations.

All adaptive optics systems also include a second mirror that monitors and corrects the slow wandering of the image that results from larger-scale motions in the air. Known as the tip-tilt mirror, it cannot use the laser beam because the fake star's round trip through the atmosphere cancels out the effect you are trying to measure. But an ordinary, dim star will suffice as a guide because the wandering affects all patches together, so the tip-tilt mirror does not need to be segmented, and therefore the image does not need to be monitored as frequently.

Now that we have the technology, nearly every telescope project in progress has been conceived with some type of adaptive optics system. Most noted among them is the Keck Observatory's dual 10-meter telescopes on Mauna Kea, Hawaii.

An important variable in this discussion is the band of light that an astronomer might choose for an observation. Infrared has longer wavelengths than visible light. A remarkable advantage of using longer wavelengths is that all factors in the technology and construction of adaptive optics systems become cheaper and simpler. Why? Because the differences in temperature and density from one atmospheric patch to the next are less destructive to infrared wavelengths of light. As a happy consequence, the effective size of an atmospheric patch is correspondingly larger, the mirror need not be as heavily segmented, and you are more likely to find a nearby guide star. Also, with less severe, moment-to-moment changes in atmospheric conditions, the guide star need not be monitored as rapidly and need not be as bright. Not surprisingly, most adaptive optics systems in use today are designed for infrared wavelengths.

No matter how effective it is, an adaptive optics system cannot see light that is not there. Large sections of the infrared are blocked by the water molecules (H_2O) in the atmosphere, and nearly all the ultraviolet parts of the spectrum are blocked by ozone (O_3). The Hubble space telescope, above the atmosphere altogether, does not, and never will, suffer from this problem. And its resolution reigns supreme in the visible part of the spectrum. Taken together, the Hubble telescope and the new generation of ground-based telescopes allow astronomers to declare that, as unromantic as it may sound, we now have the technology to "de-twinkle" the stars.

Neil de Grasse Tyson is an astrophysicist with a joint appointment at the American Museum-Hayden Planetarium and Princeton University.

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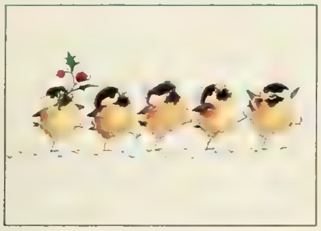

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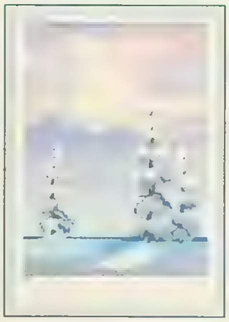

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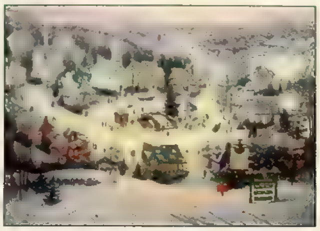

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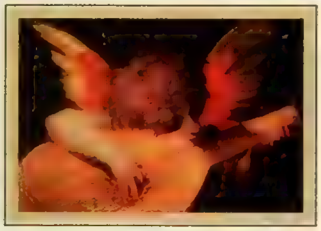

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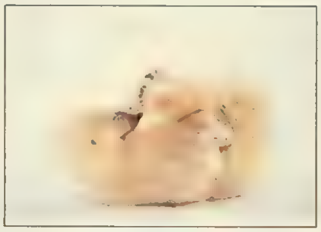

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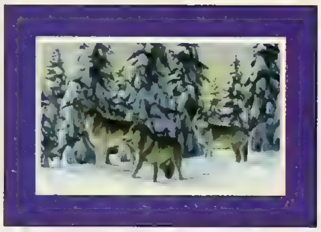

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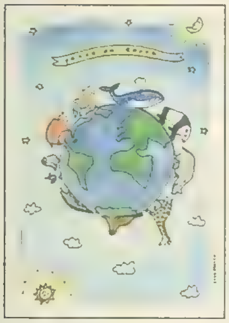

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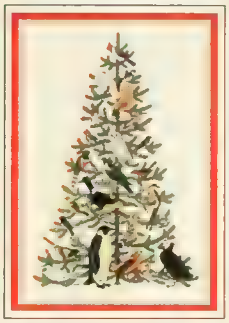

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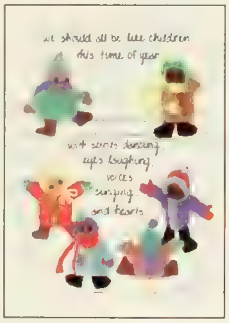

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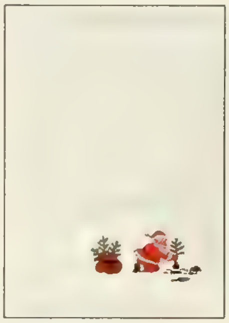

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Dawkins

(Continued from page 11)

vise gulls on how to adjust their wing and tail muscles, just such a model is almost certainly being run continuously in the brain of the gull and of every other bird in flight. Similar models, preprogrammed in outline by genes and past experience, and continuously updated by new sense data from millisecond to millisecond, are running inside the skull of every swimming fish, every galloping horse, every echo-ranging bat.

I should not wish, by using the metaphor of the computer, to imply that brains work like modern digital electronic computers. They probably don't. The principle of getting information about the real world by simulating it internally is what I want to emphasize, and the digital electronic computer happens to be a familiar and powerful tool for simulation. But there are other conceivable tools that are not digital and not electronic, and the brain might well resemble them more.

Before digital computers became readily available, engineers used a variety of devices to simulate reality. My grandfather's clothesline was a simple example. Other such "analogue" devices were, and sometimes still are, used to solve serious mathematical problems. A mathematical function, for example, can be represented as a curve of a particular shape.

As recently as World War II, differential equations were solved by elaborate mechanical analogue computers consisting of concatenations of mathematically curved cams and rods sliding over one another. Even today, the simplest way of solving that mathematician's chestnut—the "traveling salesman" problem (planning an optimal route for a salesman who has to visit a particular list of cities)—is by knotting bits of string together.

The same is true of some other optimization problems. The brain obviously doesn't tie knots in string, but the psychologist and philosopher Kenneth Craik and the biologist John Maynard Smith have conjectured (not in these words) that brain models have more in common with knotted string than with digital computers. For our purposes here, it doesn't matter. It is sufficient that the brain makes simulation models of the outside world. I think in terms of digital electronic computers because I am familiar with them, but neither their digitalness nor their electronicness is important to the analogy.

Can an animal's mental model of its world free-run into the future and so simulate future events, as does the computer model of the world's weather? Suppose we set up an experiment. Find a steep cliff in a mountainous area of Ethiopia inhabited by hamadryas baboons and place a plank so that it sticks out over the edge of the precipice, with a banana on its far tip. The center of gravity of the plank is just on the safe side of the edge, so that it does not topple into the gorge below, but if a monkey were to venture out to the end of the plank, it would be enough to tip the balance. Now we hide and watch what the monkeys do. They are clearly interested in the banana, but they do not venture out along the plank to get it. Why not?

We can imagine three stories, any of which might be true, to account for the baboons' prudence. In all three stories the cautious behavior results from a kind of trial and error, but of three different kinds. According to the first story, the baboons have an "instinctive" fear of precipitous heights. This fear has been built into their brains directly by natural selection. Their ancestors' contemporaries that did not possess a genetic tendency to fear cliffs failed to become ancestors because they got killed. Consequently, since modern baboons are all descended, by definition, from successful ancestors, they have inherited the genetic predisposition to fear cliffs. There is indeed some experimental evidence that the newly born young of a variety of species have an innate fear of heights. In "visual-cliff" experiments, a sheet of glass lies on a table and projects over the edge. Newborn animals are then placed on the glass near the edge, to see whether they shy away from the edge or are indifferent to it. The first story, then, involves trial and error of the crudest and most drastic kind: Darwinian natural selection dicing with ancestral life and death. We can call this the Ancestral Fear story.

The second story talks about the past experiences of the individual baboons. Each young baboon, as it grows up, experiences falling. Most likely, it will have enough en-

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Journal

(Continued from page 11)

ism. Sociobiology had become a political and intellectual hot potato.

"Sociobiology was bombarded," says William Irons, a Northwestern University anthropologist. According to Irons, naming their new field "evolutionary psychology" may have been a handy way for its practitioners to distance themselves from the ugly connotations still clinging to the term sociobiology.

John Tooby, codirector of the newly established Center for Evolutionary Psychology at the University of California at Santa Barbara, and one of the founders of the field, concedes that it is a direct, lineal descendant of 1960s ethology, 1970s sociobiology, and the behavioral ecology of the 1980s. "In some sense," says Tooby, "it's the same effort to locate humans in the universe and in the evolutionary sequence." So, is evolutionary psychology just sociobiology with a facelift? No, maintains Tooby, because the newer field has "*two* parents—evolutionary biology and cognitive science."

David Buss, a psychologist at the University of Michigan, concurs: "Sociobiology bypassed the mind and focused on behavior, whereas evolutionary psychology views the mind—that is, our evolved psychological mechanisms—as the central locus of adaptation," says Buss.

Tooby and Leda Cosmides, his colleague at the evolutionary psychology center, liken the human mind to a collection of computer programs in our heads. "We all have, as part of our evolved design, psychological or cognitive mechanisms that govern the circumstances under which a set of behaviors occurs," explains Tooby.

Need a mate? The mate-choice program that our hominid ancestors used is still on-line and ready to guide our choices. Need business partners? Social exchange programs are there to keep track of enemies and friends. Although they do not discount the refracting potential of culture, evolutionary psychologists also maintain that culture could not even exist without these innate cognitive programs.

Given this broad framework for looking at human action, just about any behavior is ripe for study. All you have to do is declare a behavior "universal" and then propose a hypothesis that might explain why our ancestors were selected to do it. As some of the talks at this summer's conference demonstrated, the evolutionary psychologists' position can open the floodgates to a lot of debatable studies. The papers presented at the conference, for instance, addressed such questions as why men in excounters with small cliffs to learn that falls can be painful. (If it falls down a huge cliff, of course, the experience is its last.) Pain, in trial-and-error learning, is the analogue of death in natural selection. Natural selection has built brains with the capacity to experience as pain those very sensations that, in a stronger dose, would lead to the animal's death. Pain is not only the analogue of death; it is also a kind of symbolic substitute for death if we think in terms of an analogy between learning and natural selection. Baboons build up in their brains, through experience of the pain of falling down small cliffs (perhaps through experience that the bigger the cliff, the worse the pain), a tendency to avoid cliffs. This is the second story, the Painful Experience story, of how the baboons have come to resist their natural tendency to rush out along the plank to seize the banana.

The third story is the one this is all leading up to. According to this story, each baboon has a model of the situation in its head, a virtual reality simulation of the cliff, the plank, and the banana, and it can run the simulation program on into the future. Just as the arcade computer simulates the racing car passing a tree, the baboon's computer simulates his body advancing toward the banana, the model plank teetering, then toppling and crashing into the simulated abyss. The brain simulates it all and evaluates the results of the computer run. And that, according to our Simulated Experience story, is why the baboon doesn't venture out in reality. It is a

pensive cars drive aggressively, why Caucasian women tourists in the Caribbean seek out sex with local men, and whether or not clinical paranoia is an adaptive strategy.

Is this kind of research scientifically credible? The main objection voiced by critics is that not everything people think and do may be adaptive, universal, or even functional. It wasn't during the Pleistocene and isn't now. Dan Fessler, an anthropologist at the University of California's San Diego campus, says: "They [the evolutionary psychologists] assume everything is functional. Anthropologists realized fifty years ago that not everything out there is functional."

There may in fact be a lot of noise in the system. "I think we have enough to do to explain all the behaviors that are present in at least 5 percent of the population," points out Kim Hill of the University of New

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Dawkins

trial-and-error story, just like the Ancestral Fear and Painful Experience stories, but this time it is trial and error in the head, not in reality. Obviously, trial and error in the head, if you have a powerful enough computer there to do it, is preferable to trial and error in earnest.

Now, as you read these stories, I have little doubt that you had an imaginary picture of the scene. You "saw" the cliff, you "saw" the plank, and you "saw" the baboons. The details of all our imaginary pictures are, no doubt, very different. But we all set up a simulation of the scene, which was adequate to the task of predicting a baboon's future. We all know, from the inside, what it is like to run a simulation of the world in our heads. We call it imagination, and we use it all the time to steer our decisions in wise and prudent directions.

The experiment with the baboons and the banana has not been done. If it were, could the results tell us which of our three stories was true, or whether the truth was some combination? If the Painful Experience story were true, we should be able to find out by looking at the behavior of young or inexperienced baboons. One who had been sheltered all his life from falls should prove fearless when eventually confronted with an edge. If such a naïve baboon turned out in fact to be fearful, this would still leave the other two stories open. He might have inherited ancestral fear or he might have a vivid imagination. We could try to decide the issue by a further experiment. Say we place a heavy rock on the near end of the plank. Now we humans, at least, can see from our own mental simulation that it is safe to venture along the plank: the rock is obviously a secure counterbalance.

What would the baboons do? I don't know. But I do know that, however certain I was from my mental model that the rock would be a staunch counterweight, *I* wouldn't go out along the plank, not for a crock of gold. I just can't take heights. The Ancestral Fear story sounds pretty plausible to me. What is more, so powerful is this fear that it enters into my Simulated Experience. When I imagine the scene, I experience a *frisson* of fear up my spine, however vividly I am able to simulate a ten-ton rock firmly clamped down on the plank. Since I know that all three stories are true for me, I could easily believe the same of baboons.

The imagination, the capacity to simulate things that are not (yet) in the world, is a natural progression from the capacity to simulate things that are in the world. The weather model is continually updated by information from weather ships and weather stations. To this extent it is a simulation of conditions as they really are. Whether or not it was originally designed to run on into the future, its ability to do so, to simulate things not only as they are but as they may turn out to be, is a natural, almost inevitable consequence of its being a model at all. An economist's computer model of the economy of Britain is, so far, a model of things as they are and have been. The program hardly needs to be modified to take that extra step into the simulated future, to project probable future trends in the gross national product, the currency, and the balance of payments.

So it was in the evolution of nervous systems. Natural selection built in the capacity to simulate the world as it is because this was necessary in order to perceive the world. You cannot see that two-dimensional patterns of lines on two retinas amount to a single solid cube unless you simulate, in your brain, a model of the cube. Having built in the capacity to simulate models of things as they are, natural selection found that it was but a short step to simulate things as they are not quite yet—to simulate the future. This turned out to have valuable consequences, for it enabled animals to benefit from "experience," not trial-and-error experience in their own past or in the life and death experience of their ancestors, but vicarious experience in the safe interior of the skull.

And once natural selection had built brains capable of simulating slight departures from reality into the imagined future, a further capacity automatically flowered. Now it was but another short step to the wilder reaches of imagination revealed in dreams and in art, an escape from mundane reality that has no obvious limits. □

Adapted with permission from "Worlds in Microcosm" in *Humanity, Environment, and God: Glasgow Centenary Gifford Lectures*, ed. Neil Spurway (Oxford: Blackwell Publishers, 1993).

Journal

Mexico. And every universal thought process is not necessarily a product of evolution. "There are things that are learned," says Christine Johnson, a professor of anthropology and cognitive science at the University of California, San Diego, "and we all learn them. It doesn't mean there is a specific brain module for that behavior."

Still, most scholars agree that no matter what you call the evolutionary approach, it has the potential to provide important insights into why we think and act as we do.

Take, for example, one ostensibly far-out presentation at the recent meeting. Geoffrey Miller, of the University of Nottingham, began his talk by showing a graph that separately plotted the number of homicides committed by men and by women, overlain by another graph demonstrating how many jazz albums had been produced by each sex. As expected, the graphs showed that men commit more murders and produce more jazz albums than women do. (According to Miller, males reach their peak in cultural productivity and in all activities related to sexual competitiveness in much the same way.) Men paint more paintings, compose more music, write more books, and generally become cultural icons more often than women do. But what exactly does the production of public, material culture have to do with the evolution of anything?

As Miller sees it, there are three possible explanations for the gender difference in cultural output. Men may simply be better than women at these things—but there is no psychological or biological evidence supporting such a proposal. The feminist interpretation would be that women, historically dominated by men and physically occupied by child care, were not able to express themselves in a public forum. This view has gained credence because the number of female cultural figures has increased since the feminist revolution. But still, women continue to lag behind men in the public arena, making quilts at home and writing in diaries no one will ever see. Evolutionary psychologist Miller's hypothesis? That both men and women have the capacity to produce cultural products of equal virtuosity, but that their strategies and audiences are different. Through public displays of high culture, men are striving to attract more mates, thereby obtaining more opportunities to pass on their genes. And so men may have been psychologically selected to join rock bands, write best sellers, and paint eight-foot abstracts.

Think Picasso. Think Bach. Think Mick Jagger. The evolutionary psychologists may be on to something here. □

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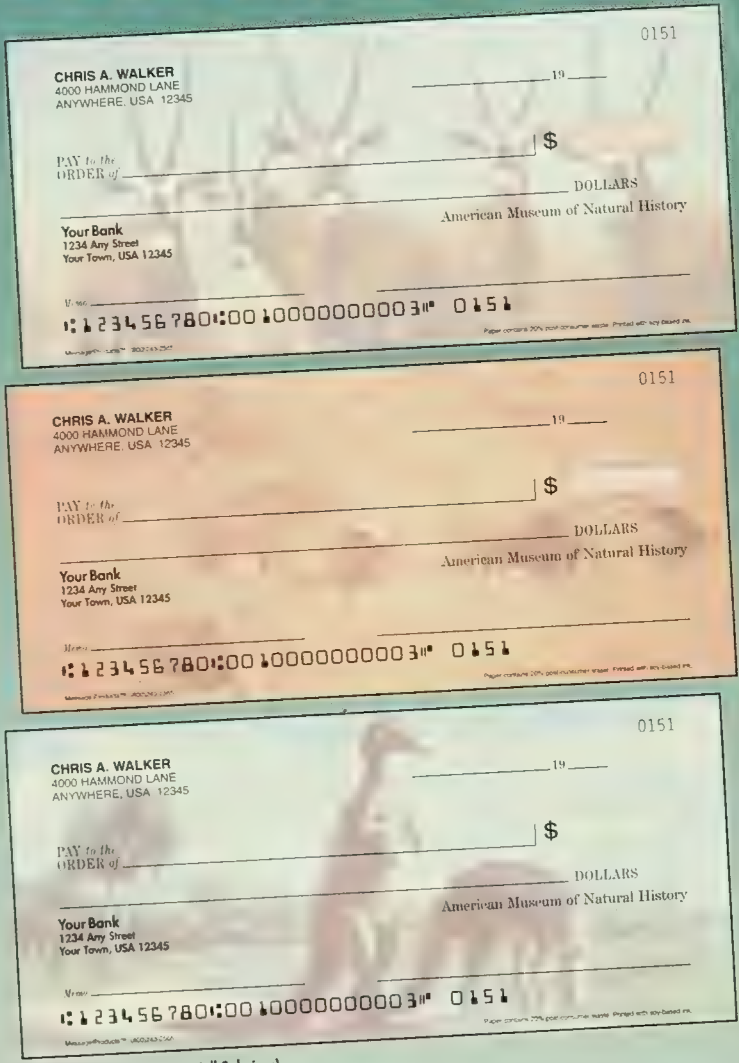

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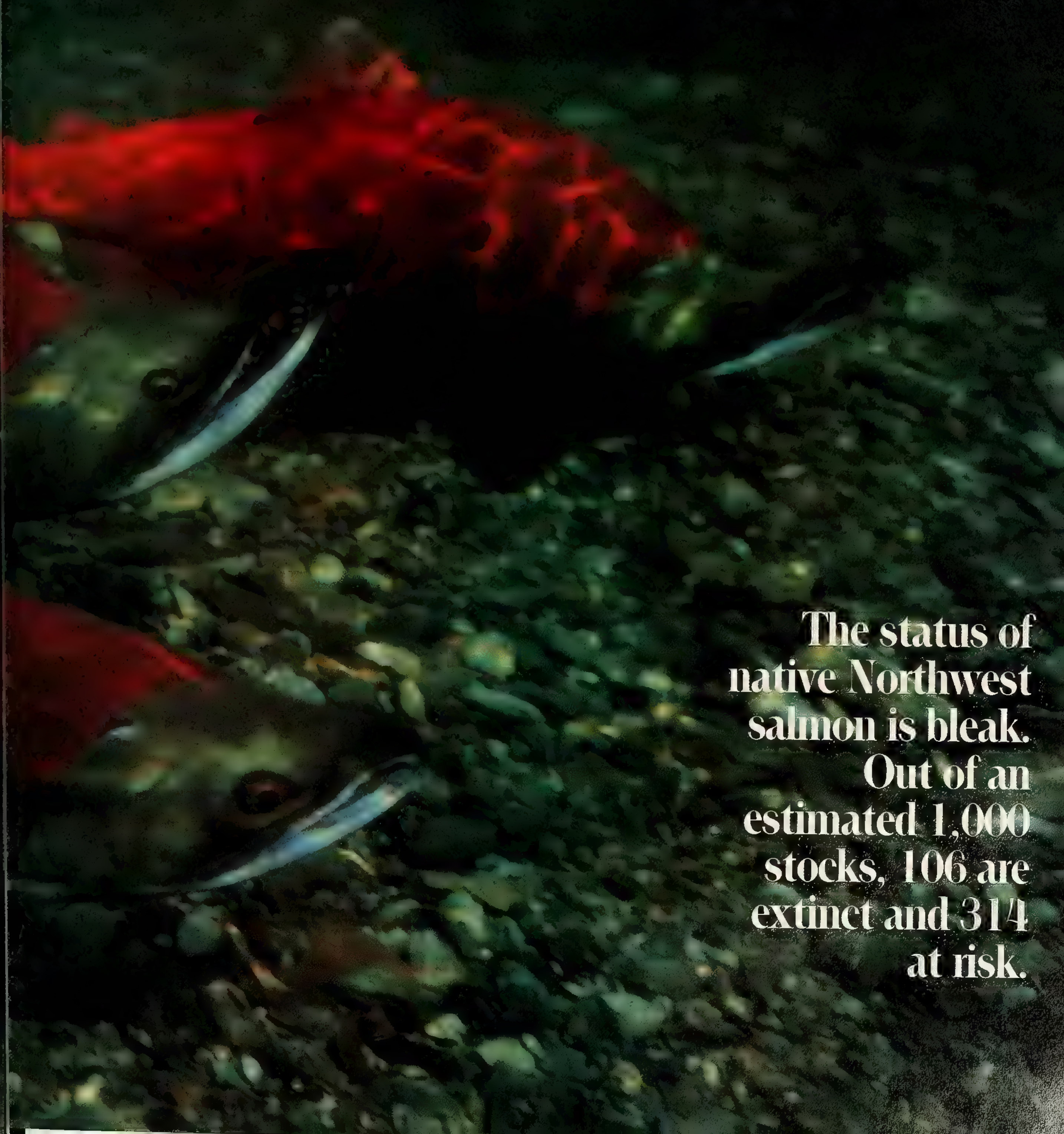
Ready to spawn, a trio of sockeye salmon swim in their natal lake.

Swimming with Salmon

New studies show we haven't understood their world. Can we learn fast enough to save them?

Text by Jessica Maxwell • Photographs by Natalie Fobes



The status of native Northwest salmon is bleak. Out of an estimated 1,000 stocks, 106 are extinct and 314 at risk.

Nearing the end of a hundred-mile-long journey upstream, this female will spawn within a hundred yards of where she hatched.

I have loved salmon rivers always; fished them for years, this one in particular for nearly a decade. It is the Campbell, on the eastern flank of British Columbia's Vancouver Island. But never have I seen it from a salmon's point of view. So, wet suit, snorkel, and flippers in place, I enter, succumb to the river's pull, and float away like a fallen mayfly. In silence I ride the green throat of the river in the glorious preautumnal warmth of September, when the salmon swim upriver, the reason for my instream baptism.

I notice the rocks first. Wonderfully magnified, the large cobbles appear muscular, important. I watch a drowned caddis fly race by, trapped on the long tongue of the current. Then I see, telegraphed peripherally by its heroic torpedo form, my first salmon. It is a pink salmon, or humpy in the local vernacular. Immediately, another fish appears, a chinook this time, the biggest and most coveted species of Pacific salmon. This one weighs at least forty pounds, and it is not alone. Five salmon are traveling together. Males mostly, I note, from their wildly hooked proboscises, the gift of procreational hormones. They move like dancers, holding their thick bodies equidistant from each other with stunning precision.

Without warning, the whole glittery gang moves five feet in front of my mask, each broad, square tail beating side-to-side like a cat's. They stay put even as the current pushes me closer. The size of their teeth is surprising. My fingers look dangerously like worms. Then I remind myself, these are spawning fish, they're interested in sex, not food.

We are almost nose-to-nose when suddenly they seem to comprehend en masse that I am neither friend nor foe but some sort of giant water nerd with terrible eyesight who has no business being in their river. And then they vanish, gone like UFOs. Their disappearance reminds me of the plight of salmon in the Pacific Northwest.

The status of Northwest salmonids is bleak. Out of an estimated 1,000 stocks of native salmon and steelhead (sea-run rainbow trout are now considered salmon) in California, Oregon, Idaho, and Washington, 106 are extinct and 314 more are at risk of extinction. In the mid-1800s, up to 16 million wild salmon and steelhead returned to the Columbia River system annually; today, despite a $1 billion salmon recovery program, fewer than 2.5 million return—2 million hatchery fish, 500,000 wild—and the numbers continue to plummet.

Wild chinook that run in the spring and summer are extinct in 63 percent of their range, and endangered, threatened, or of special concern in 31 percent. Native fall-run chinook salmon are extinct in 19 percent of their range; in peril in 61 percent. Coho are extinct in 55 percent and endangered or threatened in 33 percent; chum are

By the 1970s, biologists realized that run size depended on what happened during a salmon's first six months in the ocean.

extinct in 37 percent, pink in 21 percent, and sockeye in 59 percent. In only 6 percent to 24 percent of their original streams are the five Pacific Northwest species holding their own.

Last year, Pacific Northwest salmon officially crashed. Predicted returns for coho were at an unprecedented low across the region: 1 percent to 3 percent of their historic numbers at the turn of the century. At that time, to put this in perspective, about 123,000 native coho salmon returned to the Alsea River on the central Oregon coast. In 1951, some 89,000 returned. By 1994 the number had dropped to 1,000, and most other salmon species were also in serious decline. On April 8, 1994, tribal, federal, and state fish-management agencies agreed to shut down fishing for all coho and most chinook salmon, both offshore and in the rivers of Washington and Oregon.

When salmon hit the wall, fisheries managers finally were forced to question their methods. Denial was no longer an option for those stubbornly clinging to the old ways of fish management, especially the post-World War II entrancement with technology and the "great concrete hope of hatcheries," as it is called by Geoff Pampush, executive director of a powerful, Portland-based fish conservation organization, Oregon Trout. "For the last thirty years," says Pampush, "we've overharvested wild salmon and kept pumping out hatchery products to backfill the declines. Fisheries management agencies have never practiced sustainable harvest management on wild salmon."

It is now painfully clear that hatcheries, which are a technical solution to a complex biological problem, don't work as intended. The fish they produce are constitutionally weaker than wild salmon, which are two to ten times more likely to survive to adulthood.

"The enormous numbers of hatchery fish released each year masked the devastating decline of wild salmon," explains Paul Engelmeyer, manager of the National Audubon Society's Ten-Mile Creek Sanctuary on the Oregon coast. "When ocean conditions changed for the worse during the last three years, and both wild and hatchery salmon crashed, the mask was removed and the crisis was truly revealed."

A study conducted in 1992 at Central Washington University suggests why hatchery fish have such low survival rates. Professor of psychology Terry DeVietti observed the behavior of wild and hatchery fish in an eight-foot-long aquarium designed to simulate the flow, and other aspects, of a natural stream. Wild fish spent most of their time hiding under ledges. They grabbed their food quickly, then retreated to cover. They swam near the bottom of the tank, where the current is weakest, and conserved energy by resting in eddies. They traveled alone.

Hatchery fish ignored cover. They swam near the surface, sometimes with their fins out of the water like little come-get-me flags for predators. They wasted energy by fighting currents, and they swam in packs, all behaviors hatchery workers have noted for years. "A fish that acts that way in the wild is going to be a dead fish," concluded DeVietti.

The failure of fish hatcheries was made official in a pivotal scientific paper, "Pacific Salmon at the Crossroads," coauthored by biologists Willa Nehlsen, Jack Williams, and Jim Lichatowich and published in the March–April 1991 issue of *Fisheries,* the magazine of the American Fisheries Society. The paper articulated what many biologists had been saying all along: if the wild stocks are to survive and prosper into the next century, a new paradigm is needed that promotes the restoration of functional ecosystems rather than hatchery production.

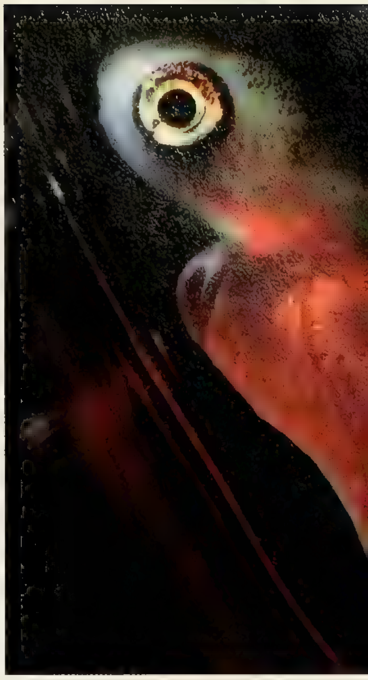
More recently, Lichatowich, the former chief of fisheries research and assistant chief of fisheries for Oregon's Department of Fish and Wildlife, completed a report on early life history patterns of chinook salmon in several Columbia Basin tributaries. "We've identified four phases that chinook salmon went through there," he says, "a period of rapid growth and rapid harvest from 1866 to 1888, then a period of sustained harvest from 1889 to 1920; the period from 1921 to 1958 was one of sharp decline, and from 1959 to the present we had a period of persistent salmon depletion."

Lichatowich maintains that hatcheries have failed to prove they can achieve their objectives. "They were going to make up for lost habitat, make up for the dams, but what we got was continuous decline. So we need to figure out where we went wrong. Secondly, we need to understand why we are still so ignorant about the ecological impacts of hatcheries, despite the fact that many people raised questions about them, especially in the '30s and '40s."

For the last two decades, one of the most strident opponents of hatcheries has been Bill Bakke, a founding member of Oregon Trout. "Hatcheries have kept us from dealing with the real problems," Bakke says, "the damage done by dams and logging, overfishing, degrading habitat, and the resultant loss of both genetic variability and the life history, which is the basis for salmon productivity. For everything."

Those, like Bakke, who saw the crash coming could take little solace in the fact that they were right. Comfort, if it were to be had at all, would come from the new studies spawned in 1994.

We've only begun to know what salmon know. They literally smell their way back to their natal stream. They know its hiding places and its predators. They know what belongs there and



The chinook's instinct to swim against the flow begins early in life, facing page. In a desperate attempt to save Snake River sockeye from extinction, biologists bred the one female and three males that returned in 1991; hatchlings, such as the one above, will keep the race alive.

One of many animals to benefit from salmon runs, a bald eagle, top, rips the flesh from a chum salmon. Salmon fillets, above, dry in a Native American smokehouse. Northwest Coast Indians still depend on the fish for a large part of their diet. A Yakima Indian, opposite page, nets salmon beneath The Dalles Dam on the Columbia River.

what does not. They even know how much weight to put on in order to accomplish the arduous swim to their spawning beds. During the one to six years they spend at sea, salmon demonstrate this kind of intimate reactivity to their oceanic environment as well.

Salmon management, it turns out, has been awash in false assumptions. The ocean was originally considered by fisheries managers to be a constant—a reliable, knowable absolute they could count on. "We assumed the ocean was a big black box that we didn't have to worry about," explains Daniel Bottom, research biologist with both the Oregon Department of Fish and Wildlife and the Center for Analysis of Environmental Change at Oregon State University.

In the late 1960s, however, fisheries biologists began to notice that salmon survival was greater during periods of strong upwelling. When surface waters are pushed offshore by prevailing winds, they are replaced by an upwelling of colder, more nutrient-rich water—just what a salmon needs. Upwelling water comes from below the thermocline, an abrupt transition zone that marks the boundary between warm surface waters and the deep waters. Because little light reaches below the thermocline, photosynthetic organisms have not depleted the nutrients there. Nitrogen and phosphorus are in rich supply. "It's like fertilizing your garden," explains Bottom. "It increases the productivity of surface waters." Phytoplankton—the base of the food chain—blooms. Grazing zooplankton populations explode. And the number of fish climbs. "In the case of salmon, even a small increase in rate of growth can make a significant difference in its ability to elude predation."

By the 1970s, biologists realized that run size was somehow tied to what happened during a salmon's first six months in the ocean. Bill Pearcy, an ocean biologist at Oregon State University, noted a relationship between the number of juvenile salmon he sampled off the Oregon and Washington coasts and the number of returning "jacks"—precocious male salmon that come back to their natal rivers, often after only six months at sea. "Pearcy found that the abundance of juveniles predicted the abundance of jacks," Bottom says, "and we already knew that the number of returning jacks predicted the number of returning adults."

New studies show that salmon survival is linked to a vast North Pacific atmospheric system that is remarkable, both for its complexity and its implications. "We're beginning to see that huge scales of variation in atmospheric conditions interact with local coastal upwelling," Bottom concludes. "This amounts to nothing less than an attempt to understand how nature works, rather than trying to force the system to make more fish."

In the Pacific Northwest these days, one often hears the demise of salmon blamed on El Niños, long periods when the trade winds subside, causing the surface waters in the equatorial Pacific to warm. The effects of strong El Niños, which have been more frequent in the last two decades, are far-reaching and can alter the flow of the North Pacific Current.

The North Pacific Current, like all ocean currents, is influenced by atmospheric conditions, especially by the Aleutian Low, a semipermanent, low-pressure zone that sits over the Aleutian Islands like a 400-ton walrus. Some scientists believe that when the Aleutian Low is strong (as seems to happen during strong El Niños), more of the North Pacific Current is diverted into the Alaskan Gyre, a huge area of mid-Pacific water, which, true to its name, gyrates counterclock-

wise in a gigantic swirl. They believe that this increases upwelling there, which turns the Gulf of Alaska into a roiling smorgasbord of plankton, krill, herring, candlefish, and squid, making salmon very happy. Alaskan fishermen caught a record 200 million salmon last year, and have averaged 135 million annually for the last decade.

Unfortunately, the diversion of the North Pacific Current results in a serious decrease in the strength of the California Current, which flows southward, parallel to the West Coast. This, in turn, reduces the flow of cold water from the north and upwelling along the West Coast of North America, thus providing at least a partial explanation for Oregon and Washington's two decades of miserable salmon seasons.

"For years, Indian and non-Indian fishermen were telling us that when upwelling didn't occur, mackerel moved in along the coast," says Terry Williams, executive director of Natural Resources for the Tulalip Tribe in Washington State, and director of the American Indian Environmental Office of the Environmental Protection Agency. "So loss of upwelling amounted to a double hit for salmon—the lack of nutrients makes weaker juvenile fish and the warmer water makes them sluggish; then the mackerel eat them. The weaker and slower salmon get, the more they look like lunch."

Could salmon cycles be governed by wide climatic wheels that move on such a slow time scale that they have escaped our notice? Lichatowich thinks so. "We've known for a while about the decadal historic climate data tree rings tell us," Lichatowich begins. On a piece of paper, he draws a lumpy line that looks suspiciously like the silhouette of a humpback salmon. "We know that cool-wet periods are good for natural salmon production and that's what we were in around 1900. From about 1920 to 1950 we were

"Historically, we have looked at salmon as being in a production mode for harvest."

Are salmon cycles governed by wide climatic wheels that move on imperceptibly slow time scales?

in a hot-dry period and salmon production went down. Then it went up again here, during another cool-wet period from the 1960s to the 1980s, which many fish managers mistakenly credited their hatchery technology for."

Lichatowich says we are now in the thirteenth year of a natural trough made all the worse by our incessant destruction of salmon habitat. "Interestingly enough," he adds, "the general climatic conditions are more favorable to salmon now than 5,000 or 6,000 years ago. It's true that the tribes fished for salmon for 10,000 years, but we now know that there was not a widespread dependency in the region on salmon until three to three-and-a-half thousand years ago." Williams adds that "our studies in the Stillaguamish River Basin, about forty miles north of Seattle, show that between 2,000 and 3,000 years ago, glacial silting settled down enough for the gravel stream beds to emerge. We found that salmon began spawning there about the time Christ was born."

Similar findings in the Columbia River Basin have come from excavations of ancient Indian mussel-shell middens by James C. Chatters, a paleoecologist based in Richland, Washington. There are three species of freshwater mussels in the Columbia, and each requires a different habitat. So Chatters dug down into the middens and measured the proportion of each species in the Indians' diet during a given period. He found that the ratio of the different species changed through time, reflecting habitat changes in the river. By measuring the annual growth rings on the mussel shells, Chatters was able to infer past water temperatures, which influence growth rate.

"What I've done," explains Chatters, "is use geological evidence and freshwater mussel shells from archeology sites on the Columbia River to reconstruct main stem stream changes there over the past 8,000 years. During that time, the stream went from a warmer, silt-laden one, to one that was more stable, gravel-bottomed and cold—that's good for salmon."

Most of these changes, Chatters says, occurred 4,000 years ago, and they happened quickly. "The forest expanded on the high ground, and at the same time, the temperature of the Northern Hemisphere dropped a bit—that was the beginning of the neoglacial period. When you increase forest density, you retard snowmelt, which stabilizes the stream flow and extends it across a greater part of summer. The forest also shades the water, so it remains cooler. Thus, we have a clear, cold, stable stream."

Then, Chatters and his scientific team modeled the effects that the environment of 7,000 years ago—a warmer climate and a turbid stream choked with silt—would have had on salmon. "We saw that it would reduce the numbers of returning salmon by one-third to two-thirds."

In order to evaluate their model and its results, they looked at fish remains—bones that hadn't yet deteriorated—in the Columbia River Indians' kitchen middens. "We found that our model results were conservative. They underestimated the climate effects," Chatters says. "Preliminary data from the middens suggest that salmon were even less numerous in the Columbia between 4,000 and 4,500 years ago. Only 23 percent of the fish remains from that time were in the genus *Oncorhynchus,* which includes rainbow trout; 77 percent were species that tolerate warm water, such as suckers and squaw fish."

Preliminary findings from middens in Hells Canyon, on the Idaho-Oregon border, corroborate the Columbia River results. "About 7,000 years ago, 90 percent of the fish eaten were indigenous and warm-water tolerant. Only about 10 percent were *Oncorhynchus*." Chatters believes that this helps explain the problems Pacific salmon have today. "Modern society has artificially recreated the conditions of 7,000 years ago. Deforestation has raised the stream temperature and silted the beds. Irrigation reduces the flow as if there were less precipitation."

When you add to this the negative impact of human activities on salmon and the effects of what Lichatowich says is the present, natural warm-dry period, you end up with a dire fish forecast indeed. "The thing that makes salmon so difficult to manage and restore is that their ecosystem is so big," Lichatowich explains. "It ranges from the headwaters of rivers out to the Alaskan Gyre and back. A salmon's life history is like beads on a string. If you break it in one spot, then the whole thing's broken. At this point, we've broken it in a lot of different places. And one of the mistakes we've made is to look for magic bullets. That's basically the hatchery problem. Hatcheries need healthy river systems as much as the wild fish do in order to be effective. If the string is broken, then hatcheries are useless. Until we take the evolutionary view that Dan Bottom describes, then every time we go into a natural trough, we're going to lose salmon, until there's either nothing left or we get the message. There's just no way around it."

Williams agrees. "We're the 10 percent society," he says. "We've used up 90 percent of almost everything, including our salmon. The real rub will come from not using that last 10 percent as seed. That 10 percent is like the last egg—you can either eat it, or you can grow another chicken." Chatters concurs. "The best thing we can do is make our first priority protecting the wild salmon stocks that are still healthy. Those are the seed for future generations in streams that may not be suitable now. The second thing we need to do is to rehabilitate the streams that could be recolonized by these salmon seed stocks. That's the long view, and that's the only way it's going to work."

Clearly, until now the long view has not been the view most taken by Pacific Northwest fisheries managers. "Historically, we have looked at salmon as being in a production mode for harvest," Bottom explains. "The whole idea of adaptation and stock differences were not part of the agricultural view of traditional fishery science, which sought to control and maximize the production of natural systems." We have just begun to understand the way salmon are tied to the landscape and how they're continually being tested in the natural environment, to which humans have added a litany of artificial stresses: stream silting and warming from logging, reduced flow due to agricultural irrigation, industrial pollution, the obstacle of dams and their fish-killing turbines, the genetic assault of hatchery fish, and chronic overharvesting. We have just begun to recognize that the productivity and abundance of salmon is made possible by the many hundreds of locally adapted native stocks that evolved to thrive in thousands of diverse Northwest streams. "Diversity is the key to the stability of species overall," according to Bottom. "As stocks go extinct, salmon lose the resiliency that has allowed them to survive for thousands of years."

Until recently, wild salmon stocks have not been treated as the precious genetic warehouses they are. Consequently, they were not properly tracked and their numbers were not known. In the spring of 1993, Oregon Trout hired three of the top biologists in the region—Willa Nehlsen, Jon Bowers, and Charles Huntington—to identify the last of the best wild Pacific salmon stocks. On December 31, 1994, their findings were published in a report entitled "Healthy Native Stocks of Anadromous Salmonids in the Pacific Northwest and California." It stands out as one of the region's most powerful and positive pieces of salmon research.

"We classified wild stocks as healthy if they were considered to be at least 10 percent as abundant as would be expected in the absence of human impacts," reported the researchers. Their final tally was 121 "healthy stocks."

"Since our society tends to push fish to the brink of extinction before beginning recovery efforts, the Endangered Species Act remains our most potent tool to protect fish," says Guido Rahr, manager of Oregon Trout's Healthy Stocks Program. "The problem is, by the time fish are candidates for listing, their populations are so low that recovery is expensive and uncertain."

If we are to succeed in saving native salmon and steelhead, Rahr instructs, then we need to protect native stocks before they have fallen to such low levels. The North Fork of the John Day

Raymond Moses, below, tunes his drum for the Tulalip Tribe's first annual salmon ceremony, held in June 1991 on their reservation near Marysville, Washington. Opposite page: In the longhouse, drummers and singers gather around cedar fires to honor the first returning salmon.

Salmon don't feed during their upstream migration. Instead, they depend on their stores of fat to reach their destination. After spawning, they die, their bodies used up by the exertion of procreation.

"Diversity is the key to stability. As stocks go extinct, salmon lose the resiliency that has allowed them to survive millennia."

River in eastern Oregon, for instance, has the last healthy stocks of spring chinook and summer steelhead in the Columbia River Basin. Other wild fish strongholds include the North Fork of the Umpqua River and the Salmonberry River in Oregon, and the Bogachiel River on the Olympic Peninsula in Washington State.

"These are some of the last holdouts for native salmon species that once numbered in the millions," Rahr concludes. "The healthy stocks inventory shows us that there are still some chances to get ahead of the extinction curve."

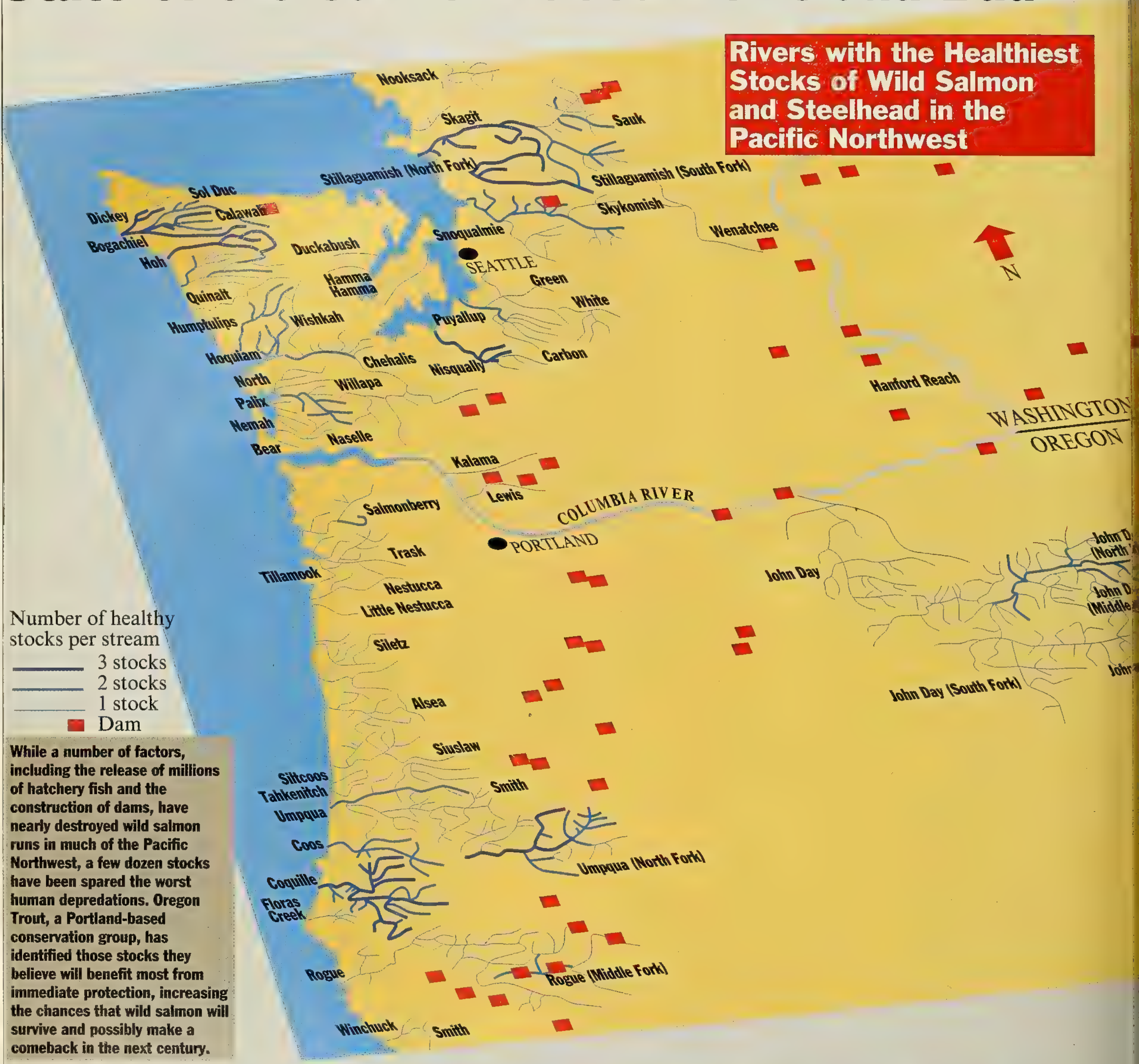
Of the 121 best wild salmon stocks remaining, thirty-six were fall chinook, twenty-one were chum, and thirty-five were winter steelhead. There were also nine healthy coho, eight pink, six summer steelhead, and five spring/summer chinook stocks identified, and only a single stock of healthy wild Pacific Northwest sockeye salmon. On a map in the report, the sockeye's home water—Washington's Wenatchee River—glows a hopeful red, like the last living artery left in the arid heart of the state. Since 1971, a remarkable 6,500 to 64,000 sockeye have returned to the Wenatchee each year, while the sockeye's return to Idaho's Redfish Lake via the Upper Snake River is down to only three fish. The health of the Wenatchee run remains a mystery.

It is a natural miracle that these fish still return to us every autumn, and that, when they die, they bring every rain-scoured salmon river a fresh infusion of marine nitrogen and carbon. On the Olympic Peninsula, twenty-two species of mammals and birds were found to use salmon carcasses in their diet. Eagles, too, consume a generous supply of salmon when it is available.

But managing for wild salmon means managing first for nature. It implies extraordinary changes in "business as usual." While industry and environmentalists duke it out in Congress, polls show that people want salmon back in Northwest rivers, and that they're willing to pay for it. John Loomis, an economist at Colorado State University, used sophisticated public-opinion research and statistical analysis to quantify the "nonmarket" value of aiding the recovery of the Elwha, a famous Olympic Peninsula salmon river, by removing two dams: $6.3 billion a year. This is why Oregon Trout is encouraging local communities to rally around restoring and protecting their salmon. And it explains why the town of Campbell River raised $200,000 to replace the salmon spawning gravel washed away by water released from a dam.

Oregon Trout's healthy stocks report has begun to circulate in the ever quickening gyre of Northwest salmon conservation conferences. There are two ways to interpret the findings: the region's rivers are either two-thirds empty or one-third full. The right way is obvious when you're nose-to-nose with a Campbell River chinook as long as your leg. □

State of the Salmon: Good News and Bad

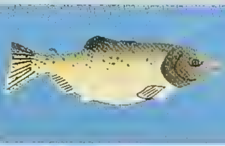
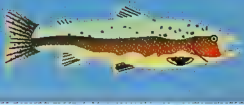
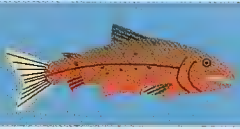
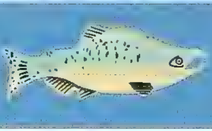

Rivers with the Healthiest Stocks of Wild Salmon and Steelhead in the Pacific Northwest
Nooksack
Skagit
Sauk
Stillaguamish (North Fork)
Stillaguamish (South Fork)
Sol Duc
Calawah
Dickey
Bogachiel
Hoh
Skykomish
Snoqualmie
Wenatchee
Duckabush
SEATTLE
Hamma Hamma
Green
White
N
Quinalt
Humptulips
Wishkah
Puyallup
Hoquiam
Chehalis
Nisqually
Carbon
North
Willapa
Palix
Nemah
Hanford Reach
WASHINGTON
OREGON
Bear
Naselle
Kalama
Lewis
COLUMBIA RIVER
Salmonberry
PORTLAND
Trask
Tillamook
John Day
John D (North
John D (Middle
Nestucca
Little Nestucca
Siletz
John
John Day (South Fork)
Alsea
Siuslaw
Siltcoos
Tahkenitch
Smith
Umpqua
Coos
Umpqua (North Fork)
Coquille
Floras Creek
Rogue
Rogue (Middle Fork)
Winchuck
Smith
Number of healthy stocks per stream
3 stocks
2 stocks
1 stock
🟥 Dam

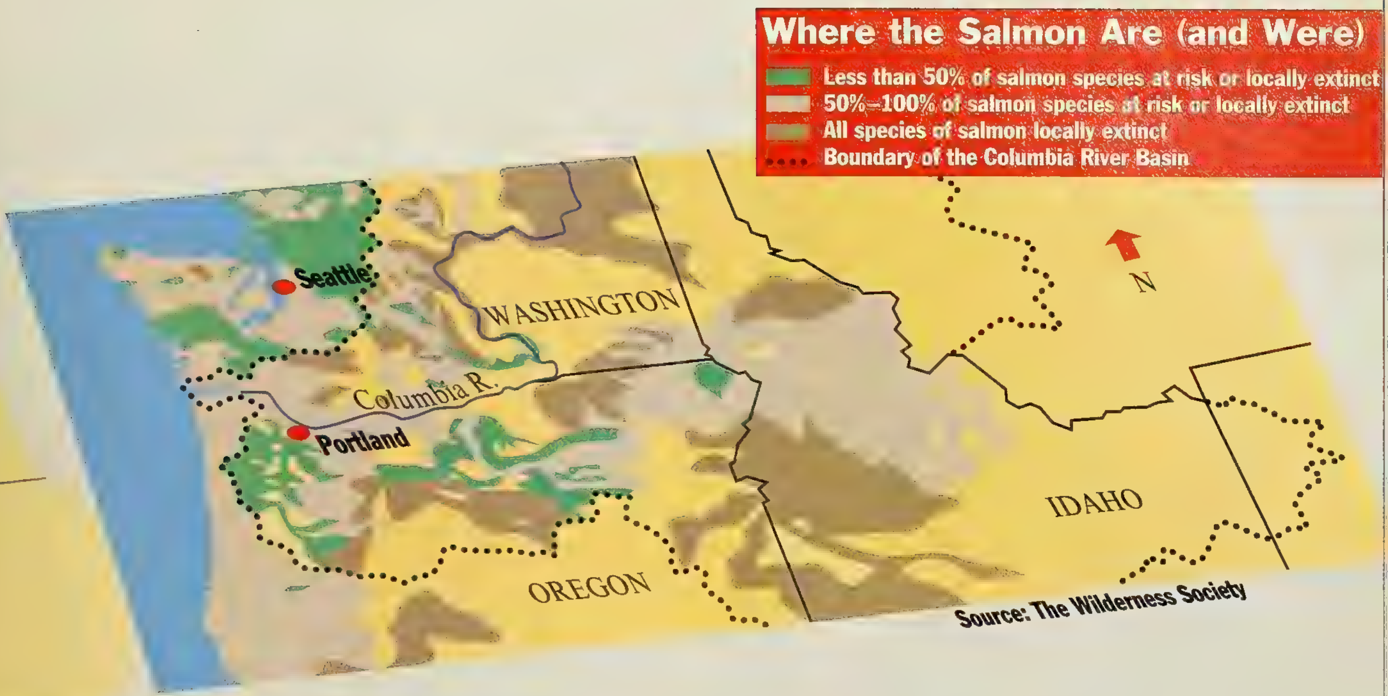
While a number of factors, including the release of millions of hatchery fish and the construction of dams, have nearly destroyed wild salmon runs in much of the Pacific Northwest, a few dozen stocks have been spared the worst human depredations. Oregon Trout, a Portland-based conservation group, has identified those stocks they believe will benefit most from immediate protection, increasing the chances that wild salmon will survive and possibly make a comeback in the next century.

The Scoreboard

A recent survey by the Wilderness Society shows how six species of salmon are faring in Washington, Oregon, Idaho, and California. Rather than looking at the numbers of returning fish, the study reflects the amount of river habitat that each species has lost.

Percentage of Historic Range Where Species Are Locally Extinct

	Species			Species	
	CHINOOK			STEELHEAD	
	Winter	88%		Summer	45%
	Spring/Summer	63%		Winter	29%
	Fall	19%			
	COHO	55%		PINK	21%
	CHUM	37%		SOCKEYE	59%



Where the Salmon Are (and Were)

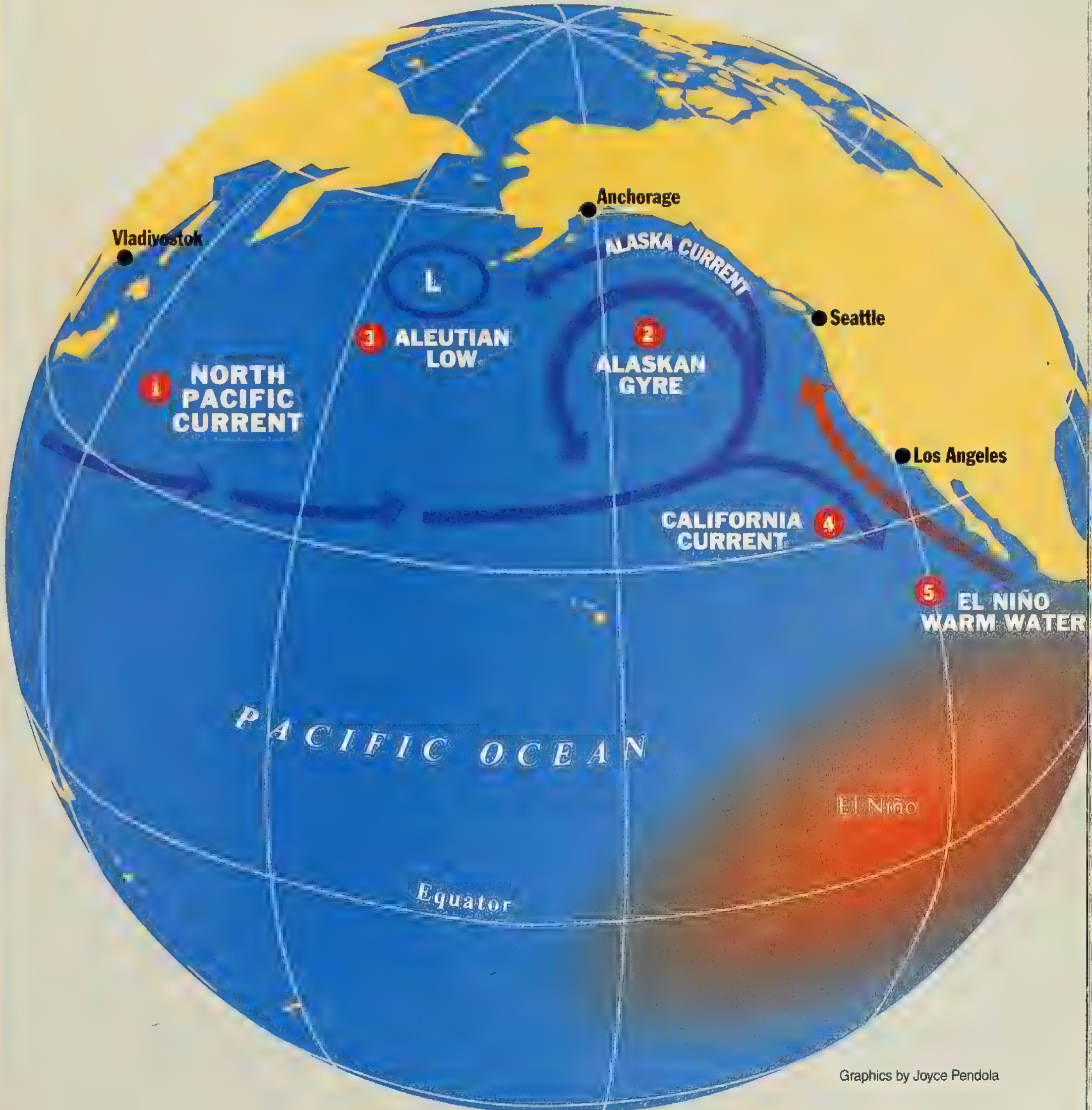
🟩 Less than 50% of salmon species at risk or locally extinct
▨ 50%–100% of salmon species at risk or locally extinct
▨ All species of salmon locally extinct
…… Boundary of the Columbia River Basin

Seattle
WASHINGTON
Columbia R.
Portland
OREGON
IDAHO
N

Source: The Wilderness Society

Currents, El Niño, and Salmon

When the eastward-flowing North Pacific Current ① meets the North American continent, some of it is diverted into the counter-clockwise-spinning Alaskan Gyre ②, increasing upwelling of deeper, nutrient-rich water in the Gulf of Alaska. When the Aleutian Low ③, a region of low atmospheric pressure, is strengthened, more of the North Pacific Current moves into the gyre, enriching the feeding grounds for Alaskan salmon. At the same time, however, the California Current ④ grows weaker, depleting the nutrients available to maturing salmon off the coasts of Washington and Oregon. In the last two decades, frequent and strong El Niños ⑤, which warm huge areas of the surface waters in the tropical Pacific, may have made conditions worse for Pacific Northwest salmon. El Niño effects are felt all along the coasts of North and South America, and may also strengthen the Aleutian Low.



Anchorage
Vladivostok
ALASKA CURRENT
L
③ ALEUTIAN LOW
② ALASKAN GYRE
Seattle
① NORTH PACIFIC CURRENT
Los Angeles
CALIFORNIA CURRENT ④
⑤ EL NIÑO WARM WATER
PACIFIC OCEAN
El Niño
Equator

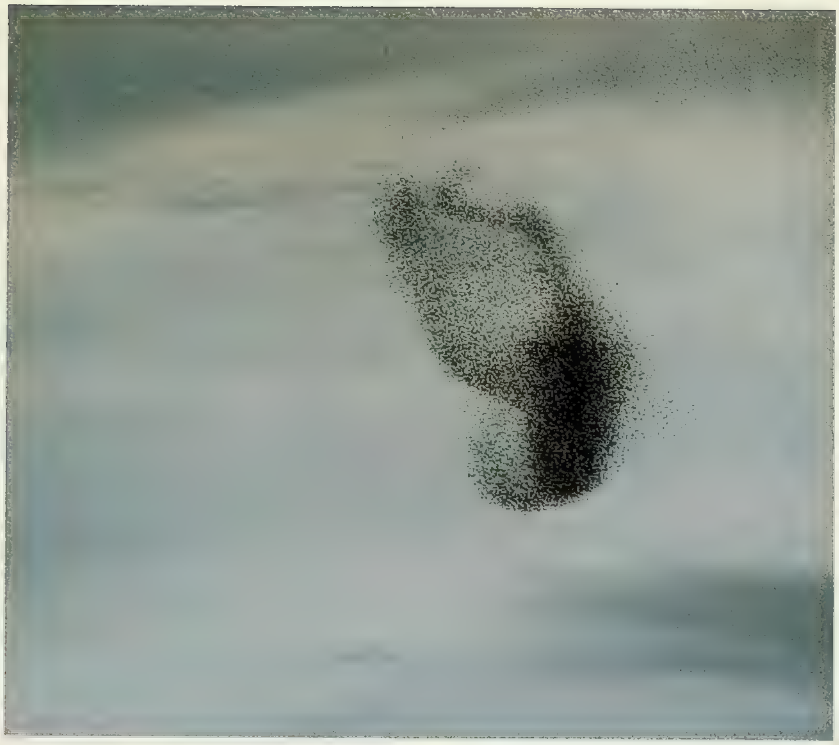
Graphics by Joyce Pendola

A Perilous Migration

Converging on their Venezuelan wintering grounds, dickcissels find danger in numbers

by Gianfranco Basili and Stanley A. Temple

In early morning, a horde of dickcissels rises from a field in central Venezuela.
Gianfranco Basili



Across the hot, dusty llanos, a huge, dense cloud of what appeared to be smoke approached us. The llanos, or plains, of central Venezuela are rapidly being converted to agriculture, and fires are common during the dry season. But this great plume was not of smoke but of birds, millions of them, flying together in a tight, undulating, serpentine flock that darkened the sky. As they reached us and flew low overhead, we were engulfed by the noise and draft created by their wingbeats. The flock, seemingly endless in length and more than a hundred yards wide, took half an hour to pass.

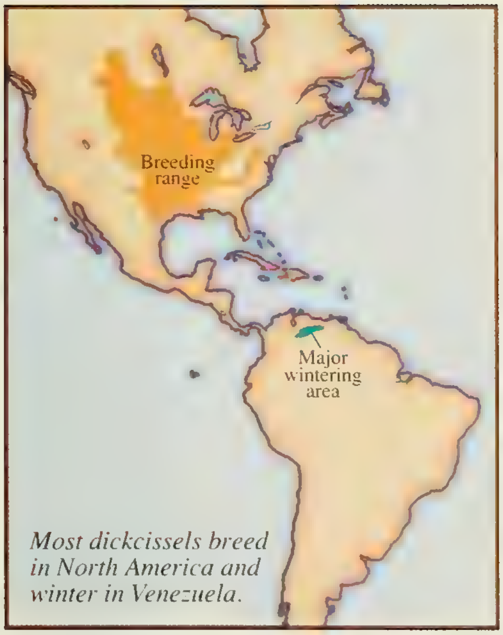
These birds were dickcissels, sparrow-sized songbirds heading for their evening roost in a nearby field of sugarcane. As the sun set, the last of them settled noisily into the cane, where they would spend the night packed together. At first light, the birds began a din that peaked about ten minutes after sunrise, just as they began to depart for the day. Forming tornado-shaped funnels, the first mass of dickcissels spiraled out of the roost; then wave after wave of birds emerged and dispersed in several directions to distant feeding sites. After just a few minutes, the roost was empty. Migrants from their grassland breeding grounds in the Great Plains of North America, the dickcissels would return to their megaroost each night during their October-to-April stay in the llanos.

John James Audubon and other nineteenth-century naturalists had described similar congregations of passenger pigeons, but such a concentration of birds is an unexpected phenomenon today. Like the passenger pigeon and the once numerous great auk, both now extinct, and like many colonially nesting species that are now en-

Sugarcane plants, left, with their sturdy stems and branches, attract great crowds of roosting birds at dusk. Above: Wintering dickcissels leave their feeding grounds.
Photographs by Gianfranco Basili

Such huge congregations of birds are an unexpected phenomenon today.

Joe LeMonnier



Most dickcissels breed in North America and winter in Venezuela.

The dickcissels' winter range is minute compared with their vast Midwestern breeding grounds.

dangered, the dickcissel is not finding safety in numbers. Even with a total population of more than ten million, the dickcissel is a species in trouble. The North American Breeding Bird Survey, a continent-wide census, showed a 35 percent decline in their numbers from 1966 to 1994.

The dickcissel's numbers are falling, along with those of dozens of other species that migrate between North America and the New World tropics, and the search is on for what is causing these species to decline. Studies of some species point to a lack of good nesting habitat or a failure to reproduce in sufficient numbers on North American breeding grounds. Other studies suggest that the declines are due to loss of habitat and a high death rate on Central and South American wintering grounds. But few researchers have followed the complete annual cycle of any single migratory species. Eager to undertake such a study, we decided to monitor dickcissels on both the grasslands of the Midwest and the llanos of Venezuela. Our four-year, year-round study has produced an unexpected explanation for their plight.

We started at home. Dickcissels breed from May through August throughout the Great Plains. This encompasses an area stretching from the High Plains to the Appalachian Plateau and from Manitoba to Texas. Within this range, dickcissels nest in a variety of grassland habitats, including native prairies, pastures, hayfields, old fields, and even roadsides.

Males arrive first and announce their presence with a song that inspired their name, "dick, dickcissel, cissel." Males may attract more than one mate, but each female is responsible for building the nest, incubating the three to five eggs, and rearing the young. Nestlings grow rapidly on a diet of insects and leave the nest about ten days after hatching.

Unlike most birds that predictably return to their previous nesting sites, dickcissels may vary as to where they settle down to nest and are especially erratic at the fringe of their range. They may be common in a region one year, only to be missing the next, even when the habitat has not changed. Their flexible and opportunistic use of range suggests that, although North American grasslands have undergone changes, there remain areas of suitable habitat unused by dickcissels in any given year.

Because loss of habitat did not appear to be the cause of the dickcissels' recent decline, we tried to find out whether the birds were having problems nesting successfully. During the 1991, 1992, and 1993 seasons, we collaborated with ornithologists throughout the dickcissels' range to monitor the fates of 600 nests. Although we found the expected amount of geographic and year-to-year variation, the overall nesting success—more than one young fledged per nest—was within the range considered adequate for a bird like the dickcissel to maintain its numbers. Ornithologist John Zimmerman, of Kansas State University, who recorded the productivity of 500 nests from 1965 to 1979, had obtained similar results. He also found that nesting birds fared no worse in the disturbed grasslands such as fallow fields, where most dickcissels now nest, than they did in native prairie, presumably their natural habitat.

We then turned to Venezuela, where almost all the world's dickcissels spend the winter (see map). In the Venezuelan llanos, the migrants converge on a winter range that is minute compared with their vast Midwestern breeding grounds. Abandoning the territoriality they exhibit when nesting, they become gregarious, feeding in smaller flocks by day and gathering in huge megaroosts by night. Our surveys throughout the llanos revealed that the dickcissels are distributed among some fifteen roosts, and that a single roost can contain up to three million birds, nearly 30 percent of the known world dickcissel population.

While wintering, dickcissels feed on the seeds of wild grasses. They also favor a few agricultural crops, especially rice and sorghum. The large-scale, ongoing conversion of Venezuelan grasslands and dry tropical forests to cereal crops could have benefited dickcissels in the same way that red-winged blackbirds and grackles benefited from agricultural changes throughout the North American gulf coast region. Provided with an expanding supply of winter food—and thus a better chance to survive the season—dickcissels might have increased in numbers. Instead, the population fell.

Because they damage rice and sorghum crops, dickcissels are considered agricultural pests in Venezuela, and farmers have developed a variety of ways to protect their fields from the menace of

A dickcissel calls from a patch of crown vetch in Mississippi. The species, known scientifically as Spiza americana, *is commonly called* pajaro arrocero, *or rice bird, in Venezuela.*
Stephen Kirkpatrick

foraging flocks. Most employ scare tactics, such as noisemakers and fireworks. But a few growers have adopted control methods that are both alarming and illegal. They use toxic pesticides, particularly organophosphates, to kill dickcissels. They poison pools where the birds come to drink, spray feeding areas just before the birds arrive, and most disturbing, they use crop-dusters to spray nocturnal megaroosts. These assaults on the roosts result in mass death, and we believe they are largely responsible for the dickcissels' decline. By targeting one of the larger megaroosts, a farmer can, in a matter of minutes, not only wipe out birds perceived as pests but also unwittingly devastate a large portion of the world's dickcissel population.

It would be easy to demonize the Venezuelan farmers. But having just returned from a two-month investigation of the impact of dickcissels on crops, we confirmed that the birds can be a serious economic burden to some growers. Is it realistic or fair to ask them to sacrifice their crops for the benefit of dickcissels? We don't think so. Instead, we believe that the solutions to the dickcissel problem will require international cooperation. Education, discovery and promotion of effective, nonlethal control strategies, and compensation for crop losses will be needed. The Venezuelan farmers and government are willing to work toward a solution. But the costs must be shared by the many who live within the dickcissels' intercontinental range: north and south, government and industry, birdwatchers, environmentalists, and farmers. One thing is certain. Unless a solution is implemented, the dickcissel will remain just a few lethal control programs away from the endangered species list. □

A crop-duster sprays a field in Venezuela, above. The birds at right were among a few thousand killed when a tractor spread pesticides over a small area.

Photographs by Gianfranco Basili

In a matter of minutes, a large portion of the world's dickcissel population can be wiped out.

Laos Keeps Its Urns

Survivor of decades of war, the Plain of Jars retains its allure

by Russell Ciochon and Jamie James

On a windy plateau in northern Laos, hundreds of three- to ten-foot-tall stone urns, some weighing as much as seven tons, lie scattered across a grassy plain. The local inhabitants say that the jars were made to celebrate a great military victory 1,500 years ago. The plain, so the story goes, was ruled by an evil king, named Chao Angka, who oppressed his people so terribly that they appealed to a good king to the north, named Khun Jeuam, to liberate them. Khun Jeuam and his army came, and after waging a great battle on the plain, defeated Chao Angka. Elated, Khun Jeuam ordered the construction of large jars to be used in making wine for a victory celebration.

The jars are at least as old as the legend claims, but if any were used for making wine, that was not their original function. In the 1930s, French archeologist Madeleine Colani documented the jars in a 600-page monograph, *The Megaliths of Upper Laos,* concluding that they were funerary urns carved by a vanished Bronze Age people. The jars nevertheless remain enig-

Each fashioned from a separate block of stone, the jars appear to have been open to the elements for centuries.

A Lao soldier, above, peers into a mammoth jar at Ban Ang, the principal jar site. At Lat Sen, right, sandstone jars are arrayed on the top of a steep hill.

Jeffrey Aaronson; Network Aspen

Russell Ciochon

matic, because after Colani's time, Laos fell into an almost continual state of war—fought over successively by the French, the Japanese, and the Americans. With peace restored, and the subsequent period of isolation ended, we visited the Plain of Jars last winter to learn about them and see how they had fared during the decades of fighting.

Unless you have an ox cart, about the only way to get to Xieng Khouang Province, where the plain is located, is to fly. As we took off in a small Chinese prop plane from Vientiane, the capital of Laos, we saw the small city laid out below us along the flat floodplain of the meandering Mekong River. The airplane leveled off at a cruising altitude of about 10,000 feet, but during the one-and-one-half-hour flight, the mountainous ground grew steadily closer. The final mountain ridge was heavily forested on its near, western side, and—in a classic example of a rain shadow—very arid and bare on its eastern side.

As we approached the airstrip at Phomsavan, the provincial capital, we saw thousands of bomb craters pockmarking the barren plain, a grim memento of the American presence in Southeast Asia. American forces dropped more than 2 million tons of bombs on Laos during the war in Indochina. Phomsavan has been built over the past twenty years to replace the former provincial capital (Xieng Khouang), which was destroyed during the war. This dusty little town became our base of operations.

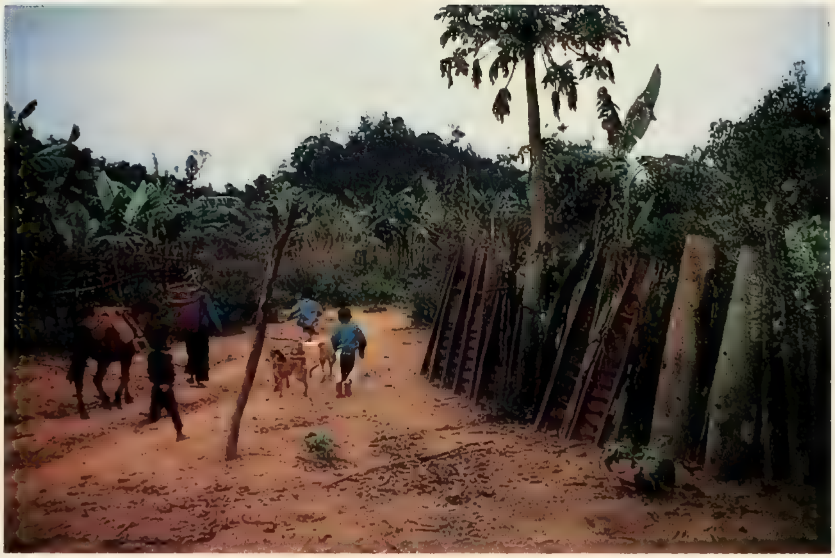
A little more than a mile northeast of Phomsavan lies the principal jar site, called Ban Ang by Colani: sixty acres of wind-swept prairie containing more than 250 urns. A huge crater on the perimeter of Ban Ang showed that a bomb had narrowly missed hitting some of the urns, but otherwise we found the jars just as Colani described them: "They are disposed without regularity, some of them pressing one against another, others quite isolated. Each one is fashioned from a separate block of stone, and a small number of them are very well executed, as though turned on a lathe, bespeaking the hand of a true artist." Fifty urns, including the largest ones known to exist, are on a ridge on the northeast edge of the site. Colani suggested that they might have held the remains of chieftains.

A few stone lids are scattered among the jars, some incised with a design of concentric rings. All the jars may have been fitted with lids, most of which were later pilfered. Another theory, however, is that these stone lids served some other function, and that the urns originally had wooden covers. In any case, all the jars appear to have been open to the elements for centuries.

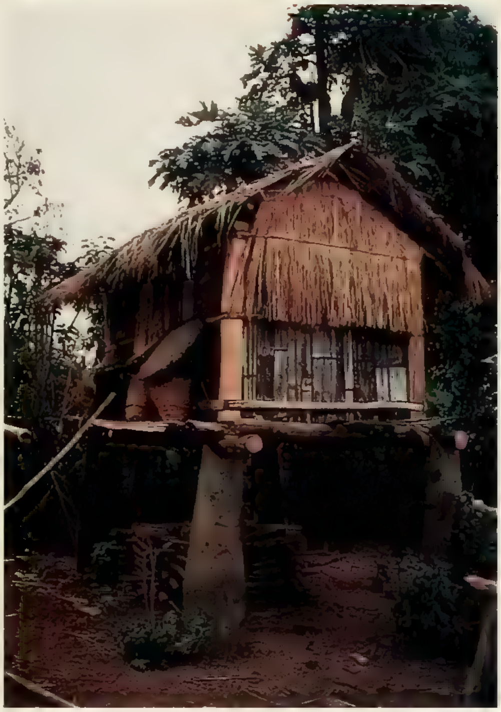
According to Henri Parmentier, a French archeologist who made a brief visit to the Plain of Jars in 1923, the urns were brought to the attention of the Western world in 1909 by a French customs official named Vinet. Parmentier wrote that local villagers had plundered the site in the intervening years: "Adults look for carnelian beads, which they are able to sell, and children find other baubles they can play with." He added that many of the jars had been broken by such "untimely excavations."

Parmentier identified three types of jars at Ban Ang: squat-shaped ones, slender ones, and others that were "almost sections of squared or rectangular prisms, with well-rounded corners." And he was able to form an idea of what a typical jar contained before it was disturbed: one or two black pots, one or two hand axes, "a bizarre object which we call a lamp," often a spindle weight of iron, glass beads, drilled carnelian beads, earrings of stone or glass, bronze bells, and frequently the debris of human bones.

Then came Madeleine Colani, a pioneering fieldworker who combined the roles of geolo-



Photographs by Jamie James



The craters that dot the landscape in Xieng Khouang Province, opposite page, are a legacy of intense bombing in the 1960s and 1970s. Other vestiges of war are the casings from cluster bombs, now used both as fencing, above, and house stilts, left.

American forces dropped more than 2 million tons of bombs on Laos during the war in Indochina.

gist, paleobotanist, archeologist, and ethnographer. Born in 1866 in Strasbourg, Colani, the daughter of a Protestant biblical scholar, decided at the age of thirty-three to move to French Indochina, where she secured a post as a natural history teacher with the geological service. She earned her doctorate in Hanoi, at the age of fifty-four, with a thesis about fossil Fusulinidae, a family of microscopic marine organisms.

A few years later, Colani began collaborating with Henri Mansuy, whose discoveries of polished stone tools and pottery in northern Vietnam (known at the time as Tonkin) pushed the archeological record in Indochina back to about 5,000 years ago. In 1923, working with Vietnamese guides, Colani discovered an enormous cache of prehistoric human remains and stone tools in a cave in Tonkin. She loaded up four dozen baskets with bones and artifacts and transported them back to Hanoi. When she arrived, Mansuy at first accused her of having raided a modern graveyard. Three years later, while excavating twelve cave sites in Hoa Binh Province, she made the first discovery of a hunting-foraging culture that we now know dates as far back as 18,000 years ago. She called this ancient stone-tool industry the Hoabinhian, the name still used by archeologists today.

Colani was accompanied in all her fieldwork by her sister, Eleonore. With their porters and guides, the two intrepid women traveled all over French Indochina, almost until their deaths, a few months apart, in 1943. The gossip among French archeologists is that Madeleine Colani made Eleonore do all the hard work, on occasion lowering her into a cavern on a rope and not letting her come back up until she found something. The human remains and artifacts the Colani sisters amassed were a landmark contribution to the study of prehistory in the region.

By 1931, when Madeleine Colani began exploring at Ban Ang, much of the jars' contents had already been looted. But by excavating around the jars, she uncovered a great quantity of objects, including bronze and iron tools, which she believed were used to carve the jars. In addition to beads made of glass and carnelian, she also found some she described as "having the appearance of baked earth," painted with bold geometric designs. Other artifacts included cowrie

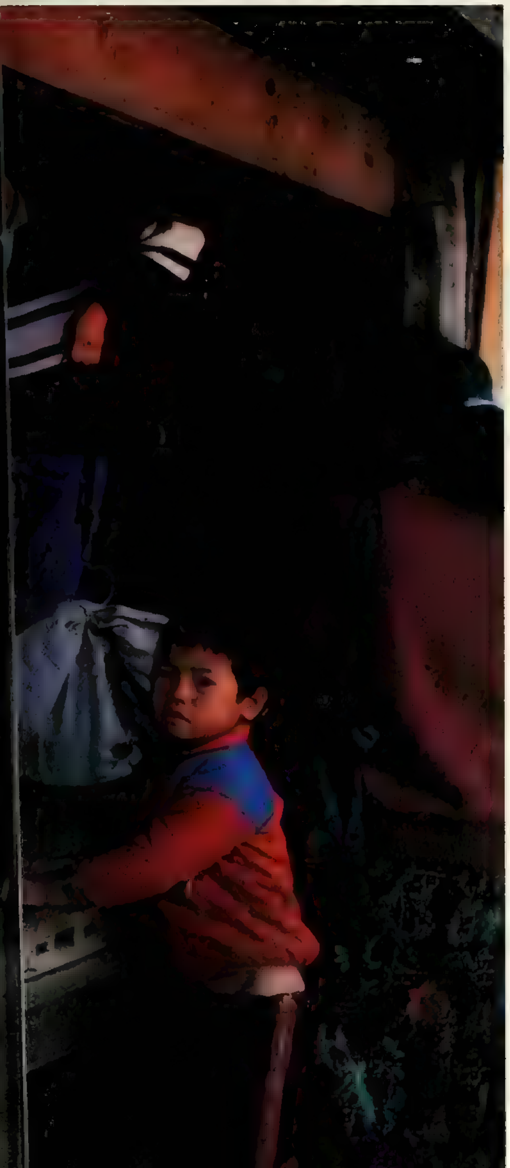
In a shop in Phomsavan, below, recycled shells are offered for sale as containers. Opposite page: A jar, carved out of granite, rests beside a jungle path some distance from the village of Ban Hin.

Nik Wheeler

shells and bronze bracelets and bells. Colani interpreted these artifacts, as well as those found by Parmentier, as burial offerings, theorizing that the urns had contained cremated remains.

Adjacent to Ban Ang is a limestone hill with a large cave. Colani excavated there and found evidence to bolster her contention that the human remains placed in the urns had been cremated. The cave mouth is at the level of the plain, and the chamber extends straight up to two natural chimneys, which were formed by the water that eroded the cave. Colani observed that the northeast wall was heavily blackened from smoke, and in her excavation of the cave she found what she believed were cinerary vases in which the corpses were burned.

While Ban Ang is the most widely known jar site in Laos, similar stone urns are found throughout Xieng Khouang Province. Another important site, which Colani named Champ d'Aviation de Lat Sen, after a French-built airstrip that existed there at the time, lies just six miles south of Ban Ang. The road there is so poor that it took us nearly an hour to cover the distance by car. At Lat Sen we observed about eighty jars, some of which had been broken apart by fig trees growing alongside or within them. Others were filled with stagnant water in which ferns and algae were growing.



The Lat Sen jars were situated on the tops of two steep hills, which were separated by a narrow gully just wide enough to accommodate the road. At the foot of one of the hills, we met a woman gathering firewood with her young children. As did other people we encountered, she gave us the popular explanation for the jars: the tale of military victory and celebratory wine. She also said that the jars were molded from a mixture of sand, sugar, and buffalo hide—a traditional view disproved by mineralogical analysis. Luis Gonzalez, a sedimentary geochemist at the University of Iowa, has examined a thin section of a Lat Sen sample under a microscope. He describes the material as a natural sandstone consisting mainly of grains of quartz, potassium feldspars, and muscovite mica, cemented by a clay matrix.

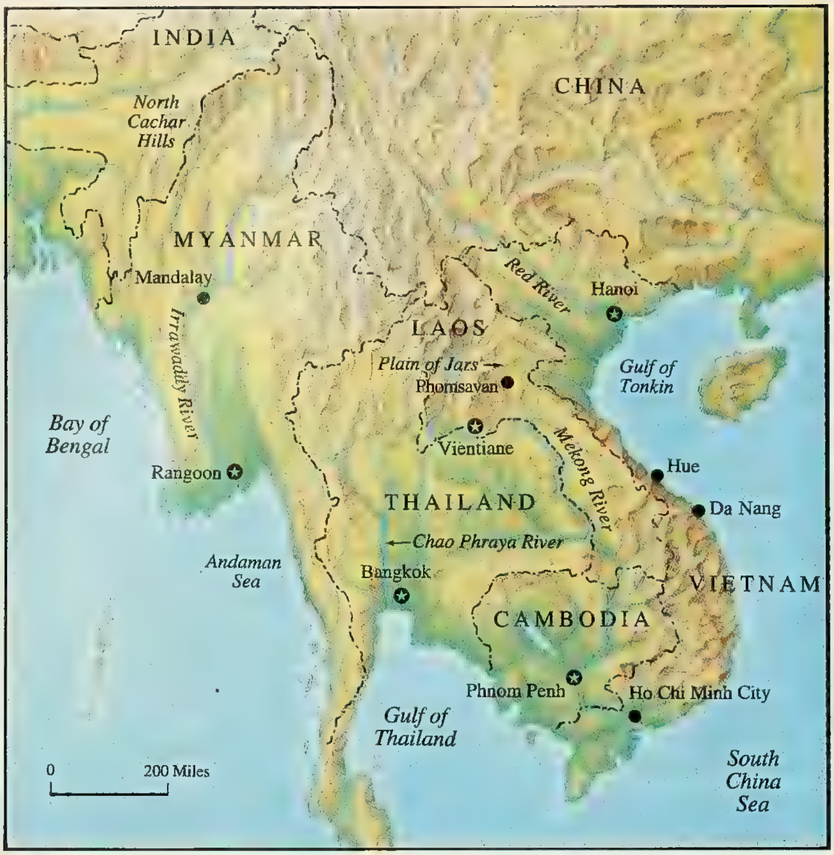
A third, more distant site we visited, which Colani called Ban Soua, lay in the middle of rice fields, at the foot of a ridge of wooded hills. Several large bomb craters bordered the site, and after consulting Colani's map, we concluded that a few of its 155 jars must have been destroyed by the explosions. Judging from the sites we visited, however, most of the jars cataloged by Colani survived the war, suggesting that they were spared whenever possible.

Wanting to see some of the jars farther off the beaten track, we pored over Colani's monograph at our guest house in Phomsavan, taking advantage of the two hours of electrical light provided before the generators switched off at nine o'clock. We settled on the village of Na Nong, where Colani had found thirty-four jars. The next morning we set off on what proved to be the roughest road yet. When we stopped an old

Russell Ciochon

Excavation of the cave, whose northeast wall was blackened from smoke, bolstered the view that the urns once contained cremated remains.

Joe LeMonnier


INDIA
CHINA
North Cachar Hills
MYANMAR
Red River
Mandalay
Hanoi
LAOS
Irrawaddy River
Plain of Jars
Phonsavan
Gulf of Tonkin
Bay of Bengal
Vientiane
Mekong River
Hue
Rangoon
THAILAND
Da Nang
Chao Phraya River
Andaman Sea
Bangkok
VIETNAM
CAMBODIA
Phnom Penh
Ho Chi Minh City
Gulf of Thailand
0
200 Miles
South China Sea

Pioneering archeologist Madeleine Colani speculated that the Plain of Jars (see map, above) lay on a caravan route stretching from the Vietnamese coast, near Da Nang, to the North Cachar Hills of India. Right: A woman with her children at Lat Sen.

woman to get directions, she explained that the village had been entirely destroyed by American bombs during the war—along with every vestige of the jars.

We drove on through the plain to the edge of the jungle and stopped at a little village called Ban Hin. It was a bustling place, filled with children playing games, and strutting turkeys fanning their tails. There, a man told us that he knew a place, about a two-hour walk into the jungle, where there were some large jars that were different from the ones at Ban Ang. Our curiosity aroused, we immediately asked him to lead us there.

The path from Ban Hin was well-worn, and we saw many people on it as we climbed through steep, rocky ravines. The shady canopy of towering teak trees was filled with colorful birds that flapped and shrieked high overhead. At the top of a heavily wooded ridge a group of girls were carrying huge bundles of firewood on their backs. They had also gathered a sackful of grubs for their lunch. Farther along, a hunter appeared with a brace of birds shot with a rifle he had made. These chance encounters brought home to us the importance of hunting and gathering for the people of Laos.

The inhabitants of Xieng Khouang Province represent a number of Laos's ethnic groups, including the dominant Lao and such hill tribes as the Thai Dam, Hmong, and Yao. Like the overwhelming majority of the country's 4.3 million inhabitants, they rely upon subsistence farming for their livelihood. In contrast to other Southeast Asian nations, Laos is sparsely populated, with a density comparable to the state of Maine.

We stopped for a rest next to a fruit-bearing bush our guide called a *mak kok.* Its small, green fruit tasted bitterly astringent at first, but with a swallow of water from the canteen, the taste became refreshingly sweet.

The forest was filled with defused American bombs, some still sticking nose down in the earth. Among them was the device favored by U. S. forces for use in Laos: the "daisy cutter," a cluster bomb with a long casing designed to scatter tennis-ball-size bomblets over a 3,000-square-yard area. The bomblets (which either exploded on impact or remained on the ground like mines) were not usually big enough to kill a man, but quite adequate for maiming adults and killing children. The woods around the Plain of Jars are still full of these hideous devices, which the people of Laos call *bombis.* As many as ten people die every month from stepping on them. But the inhabitants of Xieng Khouang put the bomb casings to good use. Most of the houses in the vicinity of Ban Hin are built on top of bomb-

Jamie James

A woman gathering firewood with her young children gave us the popular explanation for the jars: they were constructed for use in making wine following a great military victory.

casing stilts, and fences made from the casings enclose many pigsties.

We finally reached the site where the jars were located, clustered around a small clearing next to a mossy ravine. Our guide was right: unlike the sandstone jars, these were carved from a hard, dark red granite. At the site were two intact urns, one very well crafted and another that had fallen into the ravine. We also examined several broken jars off the path, but we didn't stray too far into he jungle, lest we add to the *bombi* statistics.

Colani's monograph does not seem to include his site, although it does identify two sites near vhat we think was the same village, whose name he transcribed as "Ban Him." Colani described he jars at these two sites as being made of sandtone, a point about which she was not likely to ave been mistaken, especially since she did enounter some granite jars at other locations. We nay have been the first trained observers to ecord these particular jars. That would not be so urprising, for there has been very little fieldvork in Laos since Colani's time.

A two-week excavation carried out by Japanse archeologist Eiji Nitta is a recent exception. In 1994, Nitta dug four test trenches around one of the stone jars at Ban Ang, exposing a carving of a human figure on the side of the jar, the first anthropomorphic image recorded at the site. Nearby he also discovered, eight to twelve inches below the soil surface, seven flat stones, each covering a pit. Six of the pits contained human bones and the seventh contained a two-foot-tall burial jar with small pieces of bone and teeth inside. The jar's brown lacquer surface was incised with decorative designs. None of the human remains Nitta discovered had been burned, and he found no charcoal in the trenches.

In his correspondence with us, Nitta states that the seven pits were secondary burials, a practice in which the bones of the deceased are dug up and ritually reburied. He concludes that the entire Plain of Jars was a cemetery of secondary burials. He also contends that the burial pits are as old as the jars or even older, while the jars themselves may not be as old as Colani suggested. Still, it may be premature to question Colani's interpretations. After all, she did find charcoal and burned bones in her excavations. Perhaps people placed stone urns with cremated

The main road near Phomsavan, on the Plain of Jars, right. Most Lao are subsistence farmers.
Nik Wheeler

remains in hallowed ground they knew had previously been used for secondary burials.

Then who created the Plain of Jars? Colani, who was more willing to speculate than most modern archeologists, suggested that the sites in Laos were part of a far-ranging Bronze Age culture. She pointed out that some stone jars discovered in the North Cachar Hills of northeastern India, more than 600 miles to the northwest, had roughly the same design and dimensions as the urns in Laos. J. P. Mills and J. H. Hutton, the English scholars who discovered the Indian urns in 1928, found fragments of human bones in them, which they concluded were cremated remains. They noted that cremation was still being practiced by some of the Kuki, a people who had lived in the North Cachar Hills for centuries.

Colani also called attention to Sa Huynh, a site south of the city of Da Nang, Vietnam. There, urns of baked earth containing some human remains were found buried in the sand dunes along the shores of the South China Sea. Although these remains had not been cremated, the objects interred with them—including ceramic vases, small bronze bells, and beads—resembled those discovered on the Plain of Jars.

"If our interpretation is correct," Colani proposed, "we are in the presence of three links from the same chain: the ancient monoliths of Cachar, the stone jars of Tran Ninh [Xieng Khouang], and the necropolis of Sa Huynh." According to Colani, prehistoric salt traders had followed a caravan route from Sa Huynh to Luang Prabang, located near the northwest edge of the Plain of Jars. Perhaps, she concluded, that route once extended all the way to the North Cachar Hills, and the people who lived along it shared a similar culture, burying their dead (cremated or not, depending upon local custom) in megalithic jars. Colani even drew a map, with a line connecting the three sites, and suggested that explorers venturing along this line would find yet more jar sites.

Some stone jars discovered in northeastern India, more than 600 miles away, resemble the urns in Laos.

Most scholars, including Thongsa Sayavongkhamdy, the Laotian government's director general of the Department of Museums and Archeology and the country's only trained archeologist, assign a tentative age of 2,000 years to the stone urns of Xieng Khouang, with outside dates of 500 B.C. to A.D. 300. By the latter date, complex societies based on Indian models were already prospering in the coastal regions and along the major rivers of peninsular Southeast Asia. The rise of the great kingdoms of Angkor (in Cambodia), Champa (in Vietnam), and Pagan (in Myanmar), which reached their zenith by A.D. 1000, long prevented Laos from becoming an independent power. The first kingdom of Laos was established in 1353, with its capital in the uplands at Luang Prabang. By then, the stone jars scattered over the nearby plain belonged to a forgotten past. □

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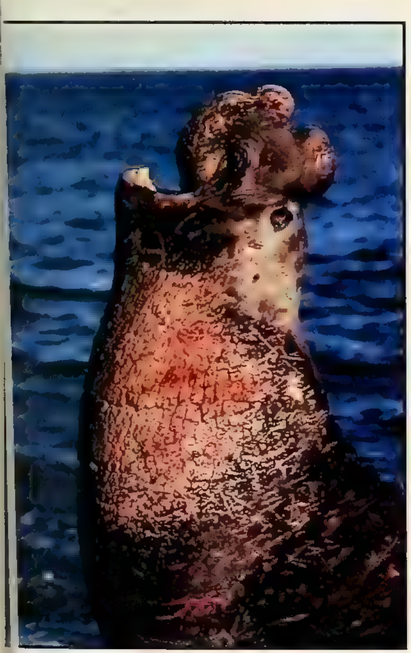

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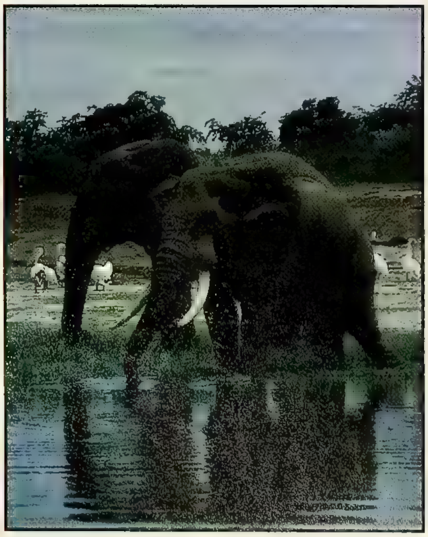

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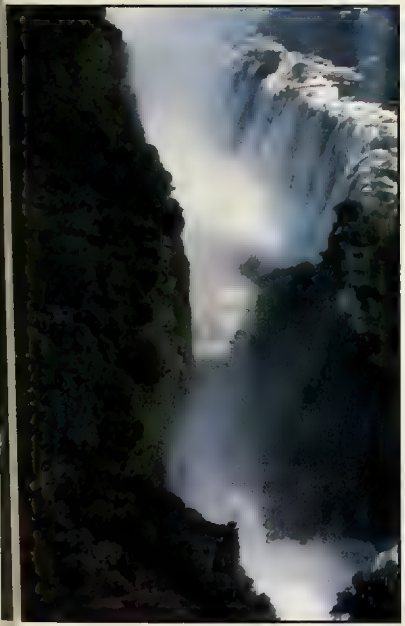

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Dr. Darwin's Diagnosis

by Mark Ridley

Why do we get sick? I can tell you why we get sick. The day after I returned home to Atlanta from an enjoyable and academically valuable conference, I knew, from the erratic behavior of my thermoregulatory system, that the flu virus had caught me. It was one of those mild but tiresomely persistent strains that took my immune system a week to clear. By then my trachea was so sensitive that I had even become susceptible to pollen, a common allergic reaction for many Atlantans but not one that normally bothered me. Anyhow, we get sick because we get breathed on.

Infections, however, are not what Randolph Nesse and George Williams are writing about in *Why We Get Sick*. George Williams is one of the century's most profound thinkers about biological adaptation, and not the least pleasure of this new book are the passages of (as I detect it) vintage Williams, in which overlooked biological problems are brought into superb focus. Williams, professor emeritus of ecology and evolution at SUNY, Stony Brook, and editor of *The Quarterly Review of Biology*, and Nesse, professor of psychiatry at the University of Michigan, address the deeper question of why we evolved to be susceptible to infection (and pollen grains) in the first place. What they call "the new science of Darwinian medicine" is the application of Darwinian theory to the understanding of disease.

Disease, whether infectious or degenerative, looks like a mistake in the diseased organism, not an adaptation, and no doubt it often is. One irritating and enervating symptom of the flu is a feverishly fluctuating body temperature. The authors' discussion of fever illustrates many of their general points. People think of fever as simply a nuisance and attack it with over-the-counter drugs. Whether this is sensible, however, depends on the function of fever. If fever is a mistake—an accidental byproduct of infection—then suppressing it makes sense. But in some circumstances fever may be the body's strategy to defeat the invading parasite. Nesse and Williams cite a study in which scientists found that infected rabbits treated with fever-lowering drugs were more likely to die than untreated, feverish rabbits. Fever may be a bug-busting adaptation, and if it is, we should think twice before suppressing it with drugs.

But Nesse and Williams hasten to explain that the idea about fever is a hypothesis, not a fact. They write: "We have lost count of how many reporters have called asking, 'So you're saying we should not take aspirin for a fever, right?' Wrong! Clinical principles of medicine should come from clinical research, not theory." Their aim is "not to instruct people on how to protect their health" but "to stimulate people to think about their illnesses in a different way." The book's main value is that it presents a set of ideas to think about.

WHY WE GET SICK: THE NEW SCIENCE OF DARWINIAN MEDICINE, by Randolph M. Nesse, M.D. and George C. Williams, Ph.D. *Times Books, $24; 291 pp.*

The chapter on allergy is one example. Allergies range from *maladies imaginaires* of uncertain origin (some would suggest that my own allergies to filling out forms and making photocopies fall in this category), which nevertheless produce genuine physiological reactions, to allergies in the medically strict sense. The latter strictly occur when something activates what must be the most puzzling armament in the immune system: immunoglobulin-E, or IgE, antibodies. As Nesse and Williams see it, the puzzle is this:

> Allergy is not an extreme action of some normally well-behaved system with an obvious function. IgE antibody seems to do almost nothing, at least in industrial countries, except cause allergy. It would appear that we evolved this special IgE machinery for no better reason than to punish random individuals for eating cranberries or wearing wool or inhaling during August.

Nesse and Williams discuss the possible answers, but the question remains open. We could surely treat allergies more intelligently if we knew what natural selection had designed the IgE system for.

Infectious disease is an evolutionary inevitability if only because the force of selection on parasites to invade us is at least as strong as the selection on us to keep them out. (And parasites have the advantage of short generation times.) But why do we suffer from degenerative diseases, senescence being the dramatic example? In the chapter, "Aging as the Fountain of Youth," the authors explain the process as a trade-off: Decay in old age is the price of health in youth. Natural selection probably tunes improvements into the age when they are most valuable, at the expense of later (postreproductive) periods.

Our bodies make trade-offs not only over the long term, between life stages, but also in the short term. We constantly allocate and reallocate our energies between different body functions. For example, a small external (or psychological) shock will divert blood flow from our stomach—digestion is one of those things that can be put off for later.

The immune system is an enormously expensive apparatus, and we suppress it when there are more urgent demands. Chronically malnourished people hardly respond at all to new foreign antigens, but once back on the road to health, the defensive phagocyte cells that ingest and destroy foreign particles, bacteria, and cell debris are fired back into action. As George Bernard Shaw's very un-Darwinian doctor says in *The Doctor's Dilemma*: "There is at bottom only one scientific treatment for all diseases, and that is to stimulate the phagocytes." Emotion comes into play here, as anxiety can depress the production of phagocytes and immunosuppress the system. Worried people, and particularly worried children, are for this reason especially vulnerable to infectious disease.

Nesse and Williams consider mental as well as physical illness. Why, they ask, are so many people racked by anxiety? Why is it that we spend so much of our lives, as Mark Twain said, "suffering from tragedies that never occur"? They point out, however, that it is just as possible to have too little anxiety in relation to real dangers as it is to have too much for imaginary ones. If so, what might the side effects be of worry-reducing, happy drugs? Depression, for example, may in part be an evolved psychological adaptation for dealing with hierarchical social competition: "Some low mood may be a normal part of status competition." Nesse and Williams wonder wryly, "What will happen in large corporations as more and more depressed employees start taking anidepressants?"

The crucial part of Darwinian medicine s to establish, for any aspect of sickness, vhat kind of adaptation (if any) it is. Is ever an adaptation of the host to reduce nfection or of the parasite to prolong it or f neither (in which case it should make no lifference to the infection)? Given our resent knowledge, we may simply not now the answer. In reading *Why We Get ick,* however, we stop, think, and perhaps ven appreciate that behind the flu or alergy symptoms that are making us feel vretched is a valiant effort of our system ultimately work for our own good.

lark Ridley is an assistant professor of nthropology and biology at Emory Uniersity in Atlanta. His most recent books re The Problems of Evolution *and* Anial Behavior: An Introduction to Behavoral Mechanisms, Development, and cology.

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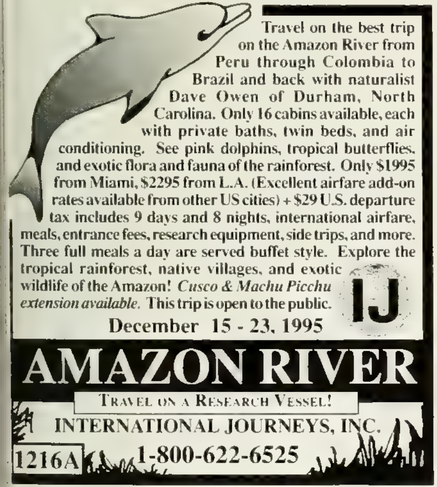

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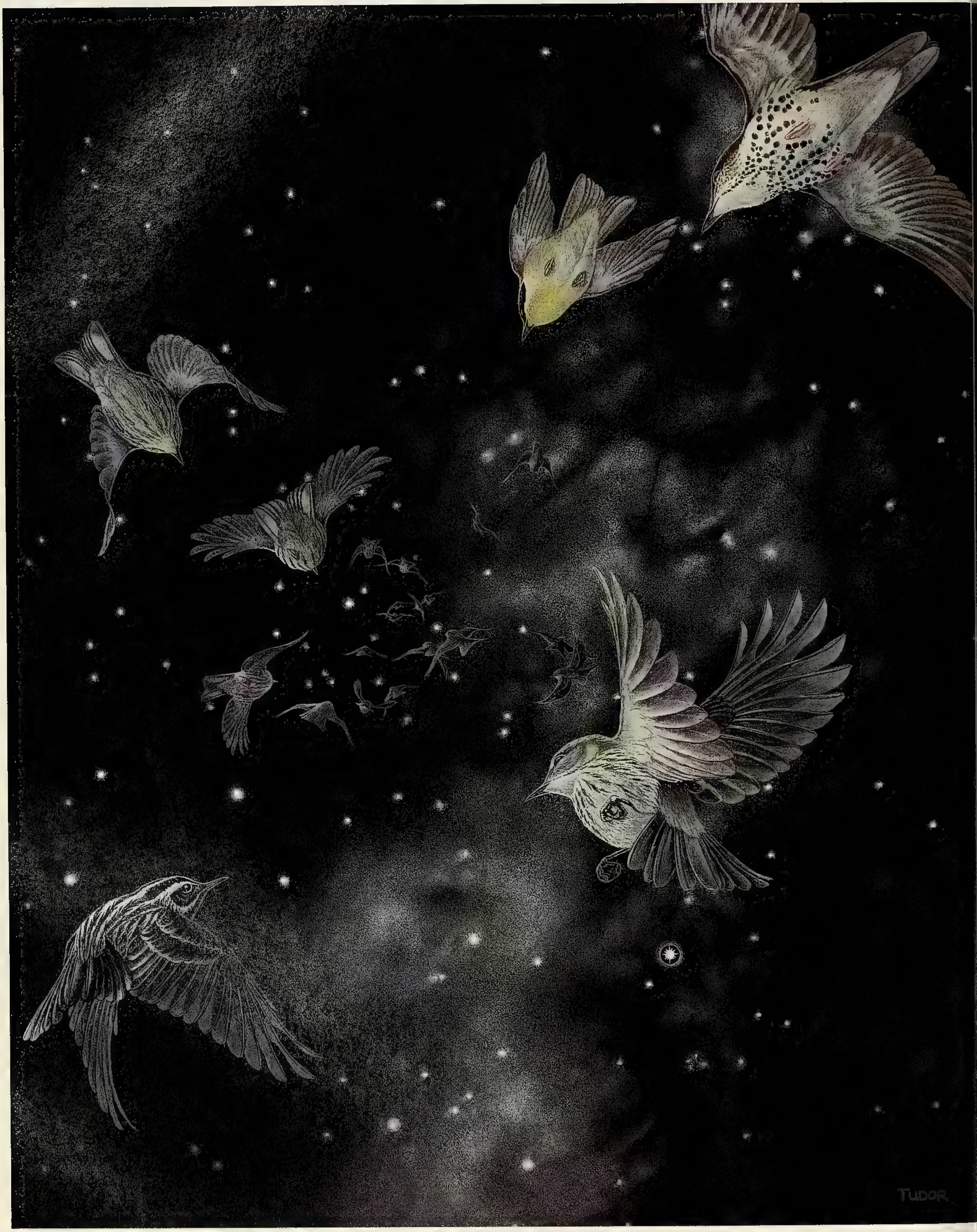


Warblers and thrushes ply the night sky southwest of Cape May Point in late September.
Painting by Guy Tudor

Night Flight

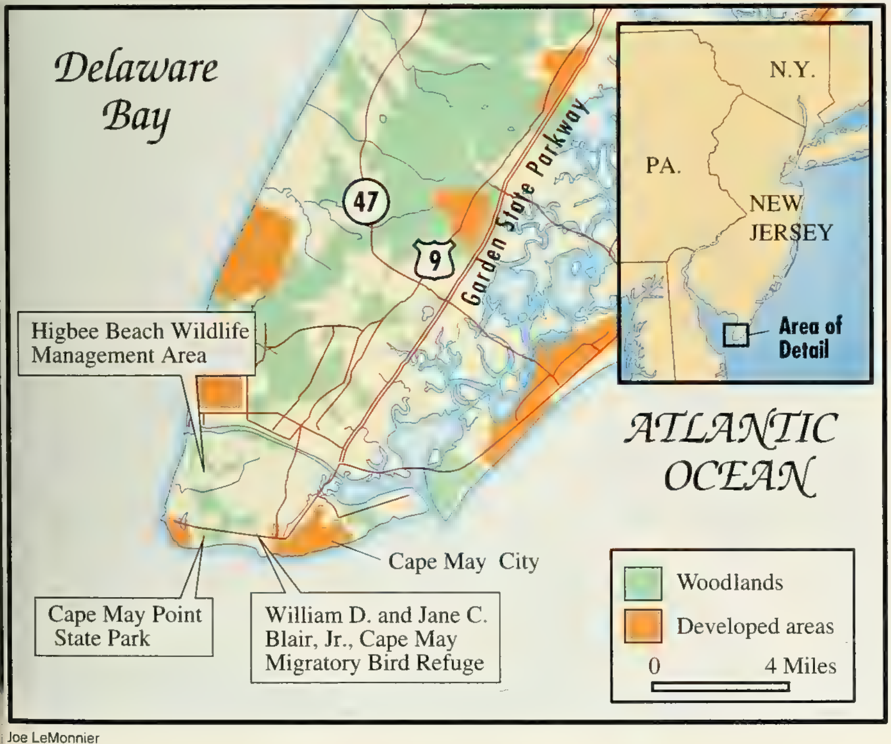
by Paul Kerlinger

"Zeeet!" Silence. Seconds later, "bveeoh!" Songbirds migrating invisibly over my head call almost incessantly. At 4:30 a.m., the sun has not yet risen, but the migration has been well under way since about a half hour after sunset the previous evening. These birds have been aloft more than eight hours. The calls of an early September morning in Cape May, New Jersey, belong to warblers, thrushes, grosbeaks, and other songbirds. Most are en route to Central and South America, with some venturing to the Amazon Basin and beyond. During this arduous trip, nighttime flight is the rule.

Birds that soar and glide on fixed wings, such as hawks, vultures, eagles, storks, pelicans, and some cranes, almost always migrate in daytime, because they depend on vertical currents of air, called updrafts or thermals, that are generated when the sun heats the earth. But the many birds that use powered, or flapping, flight, tend to migrate at night. In North America, Europe, and much of Asia, most migrant songbirds and shorebirds, and many waterfowl, travel under cover of darkness. For most, flight commences thirty to forty-five minutes after sunset and peaks three to six hours after takeoff, although some birds migrate throughout the night.

As revealed by radar, takeoff can be explosive. Within a few minutes, a clear radar screen can become cluttered with thousands upon thousands of tiny echoes. Sidney Gauthreaux, of Clemson University, has determined that during peak migration, as many as 50,000 migrant songbirds per hour pass through each linear mile scanned by radar. From studies and counts of birds that have been killed in collisions with television and radio towers, lighthouses, tall buildings, and smokestacks, we know what types of birds are likely to be making the echoes on the radar screen. Radio and television towers extending more than 600 feet above the ground are responsible for the deaths of many night migrants, which are often attracted to lights on the structures.

Nocturnal migrants are sometimes compelled to fly in daylight. When birds cross large bodies of water like the Gulf of Mexico, they cannot complete the lengthy trip in a single night nor can they land on the water. Semipalmated and other sandpipers take off from tidal flats a few hours before sunset, at times when high tides preclude feeding on the flats. When the tide is low, these shorebirds feed until sunset and take off shortly thereafter.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Night Sights

If you want to see and hear the phenomenon of nocturnal flight, go outside on a clear spring or fall night. A half to full moon is ideal. By looking through powerful binoculars (15 × or greater magnification) or a telescope fixed to a tripod, you can see migratory birds passing the moon's disk. Watch for "dots" that move across the moon; sometimes you can even see wings flap. Listen for the faint chips, zips, zeeps, and sip calls of songbirds. The familiar honking of Canada geese and brant can sometimes be heard, as can the hoarse croaks of egrets and herons. Of course, a place beyond the city and suburbs is best, because traffic noises obscure the delicate nighttime vocalizations of most birds. But if you can find a quiet spot on a September, October, April, or May night, look and listen. In most of the United States and southern Canada, you should be pleasantly rewarded.—*P. K.*

Many night migrants also make "morning flights." In the gray light of dawn, warblers, orioles, tanagers, grosbeaks, and some sparrows may be heard but not readily seen. After completing a night's leg of their migration and landing, these birds take to the air again, usually at dawn or soon after. Most morning flight is over within two or three hours after sunrise, although it can continue until nearly midday. Why should these tired migrants take off again after sunrise? At Cape May, songbirds engaged in morning flight head northward up the peninsula, the wrong direction for fall migration. They are seeking specific feeding and resting sites that they could not find during the previous night. Morning flights are short and low, less than 300 feet above the trees. From this height, the birds can see the ground and evaluate potential habitats in which to feed and rest.

These exceptions to the night migration rule suggest that the birds vary their behavior in accord with changing conditions. Occasional daytime flight is an adaptation that helps night travelers complete migration as safely and quickly as possible.

Among powered fliers, which birds are

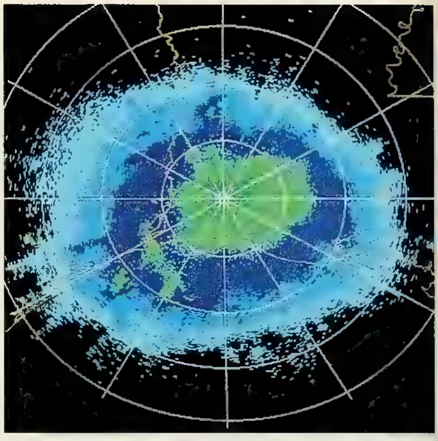
most likely to fly at night? There are no hard and fast "rules," but there are trends. Birds that travel from the Northern Temperate Zone to the Tropics in fall are more apt to fly at night than are migrants that remain within the continent where they nest and raise their young. Even among migrants that do not leave North America, Europe, and northern Asia, species that migrate farthest fly at night more often than those that travel shorter distances to their wintering grounds. The songbirds coming through Cape May by day are mostly short-distance migrants from the north, such as finches, waxwings, blackbirds, blue jays, American robins, goldfinches, and pipits. Their migrations begin before sunrise and are often over before midday.

In North America, birds that head south before early October are more likely to migrate at night than those that migrate from mid-October through December. In November at Cape May or Montauk, at the tip of Long Island, New York, thousands of red-throated loons, scoters (sea ducks), northern gannets, snow geese, Canada geese, and gulls can be seen winging south in formation by day, but some are flexible in their timing. Canada geese, for example, are comfortable migrating during the day, but their honking can as often be heard from the night skies.

For many years, nocturnal migration was explained as an adaptation that enabled some birds to avoid predators by flying in the dark, and that allowed them to forage in daylight. While both theories may be correct in part, neither explains the phenomenon adequately or for all species. Many large birds, like geese, ducks, and herons, that migrate both day and night, are rarely at risk from predators. Also, some waterfowl and other nocturnal migrants, such as shorebirds, are adept at feeding in darkness. Except for the stars, the navigational cues that birds may use to find their way—for example, polarized light, magnetism, and wind—are also available during the day.

A more encompassing explanation for nocturnal migration is based on the atmosphere itself. During migration, birds must contend with wind, air temperature, and turbulence. The air through which they fly has been the most significant factor in the evolution of their behavior, structure, and physiology. I believe it is no less important in shaping migratory behavior. The daily cycle of predictable atmospheric changes profoundly influences a bird's flight.

The atmospheric boundary layer—the band of air that is influenced by the earth's surface—is dynamic. It expands during the day and shrinks at night. Shortly after sunrise, the sun begins to heat the earth, creating thermal convection, or turbulence, which includes the thermal updrafts used by soaring birds. From midday through midafternoon, if skies are clear and if the air is cooler at higher altitudes, thermal activity becomes intense. Thermals rise like columns to 5,000 or more feet above the earth's surface, and the vertical airflow in updrafts can exceed ten miles per hour. Wind direction and wind speed shift almost constantly. If the upper layer of air is warmer than the lower—a phenomenon known as an inversion layer—thermals do not rise to high altitudes. Also, because water is usually cooler than air, thermals rarely form over lakes or oceans. When they do, they are weak and widely spaced. The air over large bodies of water is therefore much less turbulent than it is over land. (For this reason, soaring birds migrate over landmasses and land bridges, where they can ride thermals, rather than over water.) At sundown, the atmosphere cools and turbulence diminishes. By midnight, air near the earth's surface averages about one to twelve degrees Fahrenheit cooler than at midday, and the atmosphere is calmer.



Radar colors indicate relative densities of birds in the air. The radar reading above shows dense migration on the night of October 24, 1994, at Lake Charles, Louisiana. Opposite: Canada geese silhouetted against a full moon

Sidney A. Gauthreaux, Jr.

Anyone who flies frequently has probably experienced turbulence. As a plane flies through the first 5,000 feet of the atmosphere during the day, it also passes through thermals, creating those disconcerting "bumps." If this turbulence is strong enough to bounce a jumbo jet around, think what it does to birds trying to fly in a straight line. Flying at only fifteen to forty miles per hour, small songbirds and shorebirds have a difficult time maintaining a steady flight path. After dark, when thermal activity ceases and the air is smooth, small birds can more easily stay on course, without having to correct for updrafts and turbulence.

Cape May Bird Guide

Although Cape May is a birding hot spot throughout the year, the best viewing times coincide with migration. Songbirds, seabirds, hawks, loons, waterfowl, and shorebirds move southward through the area from mid-August to mid-November. The hawk watch in Cape May Point State Park offers the best action from about September 20 through the first week of November, with the first ten days of October yielding the most spectacular flights. For loons, gannets, and sea ducks, the first half of November is great. Watch from the 7th Street and 8th Street jetties in Avalon.

In spring, the shorebird and songbird migration peaks between the last days of April and the end of May, and during this time you can also see many of the birds—such as egrets, terns, and songbirds—that stay on to breed. From about May 15 to May 30, the sandy beaches of Delaware Bay host hundreds of thousands of red knots and other sandpipers feeding upon horseshoe crab eggs.

In spring and autumn, try Higbee Beach Wildlife Management Area for songbirds. The Cape May Migratory Bird Refuge offers good viewing practically anytime. More rarities are seen in its meadows and marshes than anywhere else in Cape May.—*P. K.*

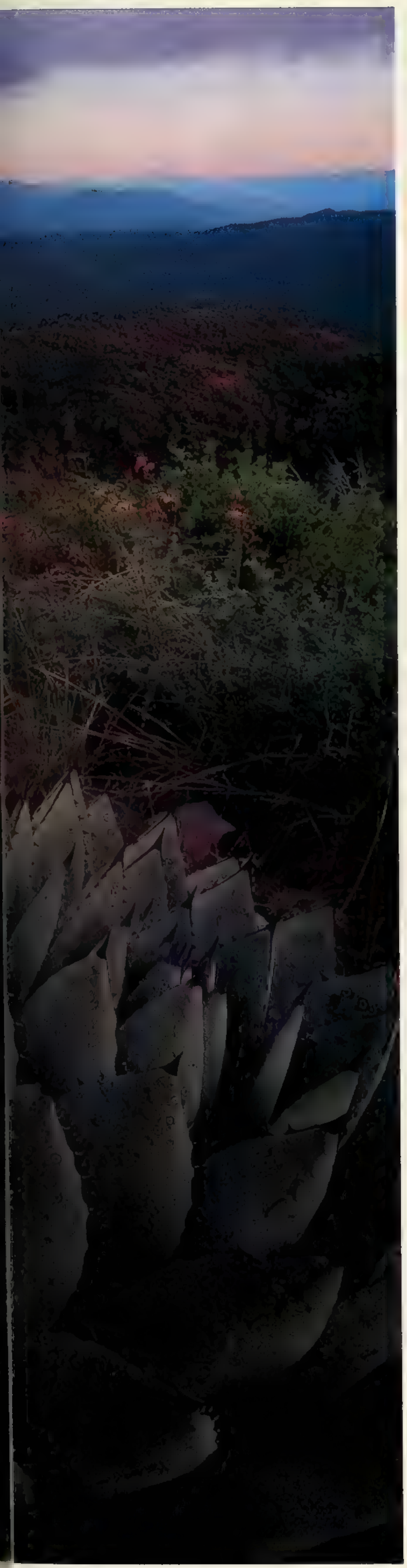
For more information on birding in Cape May, contact the Cape May Bird Observatory at 609-884-2736.

Air temperature also affects flight. Flapping birds generate great heat; resting body temperatures of almost 100° F increase to between 105° and 110° F during strenuous flight. Although birds can tolerate these high body temperatures, they still must avoid overheating. One way to do this is to fly at night or, in the case of daytime migrants, to fly in cooler seasons and to avoid flying at midday. Those ducks and geese that head south early in the season often fly at night.

Convective and evaporative cooling also help control a bird's temperature. Convective cooling results when air moves across the skin, creating the feeling you experience when holding your arm out of a window of a moving automobile. The cool night air passing over a migrant's body acts the same way. Although birds do not have sweat glands, water passes through their skin, and water evaporation from the skin surface, as well as from the mucous membranes lining the respiratory tract, promotes cooling. While evaporative cooling is good, too much water loss is bad. At night, birds can fly for longer periods because they will not overheat as rapidly or lose water to evaporative cooling as quickly as they will during the heat of the day. This may be one of the primary reasons why so many birds headed for the Tropics migrate at night.

From July through early September in the United States, daytime migration is minimal, but after dark, songbirds, shorebirds, and some waterfowl are aloft and on their way to far-off wintering grounds. In the cool, calm night, they move southward by the millions, their flight shaped by evolutionary forces and by the very air through which they move. □

r. Scott Nielsen; Bruce Coleman Ltd.



Diamond Point, Arizona

by Robert H. Mohlenbrock

Extending more than 200 miles, from northwestern Arizona into New Mexico, the Mogollon Rim is the irregular southern edge of the 9,000-foot-high Colorado Plateau. Along the rim, the terrain may drop rapidly down to 6,000 feet, before beginning a much more gradual descent down to 3,000 feet. A moist, ponderosa pine forest prevails on the plateau, while the region below is dry, supporting scrub forests and desert plants.

Much of the Mogollon (pronounced muggy-own) Rim area falls within four national forests that offer visitors a variety of campgrounds, picnic spots, fishing lakes, and scenic trails. One natural attraction—Chitty Canyon, Arizona—was featured in the August 1994 issue of *Natural History*. Another is Diamond Point, a protuberance that is part of the rim topography, but which lies ten miles south of the plateau, rising from a 6,000-foot base to 6,384 feet. Located in Tonto National Forest, Diamond Point receives its name from the quartz crystals scattered over the rocky terrain and included in many of the rocks. In the sun, Diamond Point truly glistens.

Century plants and other chaparral vegetation cloak Diamond Point, left. Above: Cushion cactus blooms

All photographs by Jack Dykinga

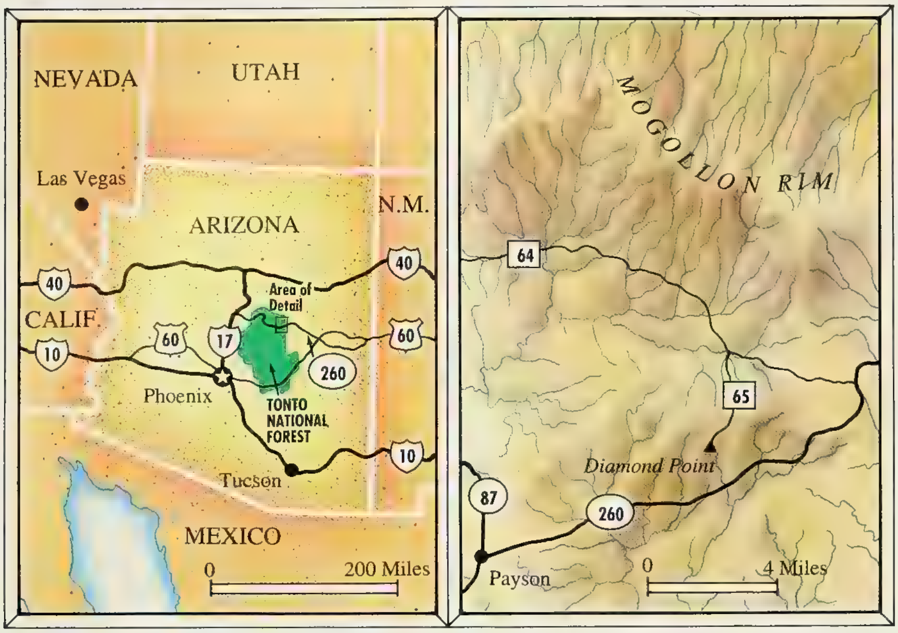
Part of the route to Diamond Point—along what is known as the Control Road, or Forest Highway 64—parallels a stream. New Mexico locust, Lowell ash, and Arizona walnut line the streambank, while grasses cover much of the forest floor. Here and there, a touch of color may be added by the blooms of lupine, scurf pea, beardtongue, milfoil, wild geranium, or the shrubby wild Arizona rose. But after the final turnoff onto Forest Highway 65 toward Diamond Point, this lush vegetation falls behind. As the road begins to climb above 6,000 feet, the soil becomes extremely dry and rocky, and the plant life gives way to a uniquely western habitat known as chaparral.

The word *chaparral* derives from the Spanish for evergreen oak; in Arizona it refers to a habitat dominated by shrubs and a stunted species of live oak, with relatively little ground cover provided by wildflowers and grasses. In general, Arizona's chaparral plant communities develop at between 3,000 and 5,500 feet, but in some places, such as Diamond Point, these limits differ as a result of slope exposure, soil type, and climate. Below 3,000 feet, chaparral tends to merge into desert scrub or desert grassland. Above 5,500 feet, chaparral usually gives way to forests of small (thirty-foot) pinyon pines, one-seed junipers, and alligator junipers—woodlands that are sometimes considered part of the chaparral but are more accurately termed Madrean woodland for their association with plant communities of the Sierra Madre.

Most of the plants in the true chaparral are trees and shrubs eight to ten feet tall. These plants usually have a multitude of branches; broad, leathery, evergreen leaves; a dense, compact crown; and a very deep root system from which new growth sprouts readily. In the drier sites, chaparral shrubs and trees cover only about 40 percent of the ground, while in more moist areas, they may provide twice that cover.

The most abundant plant is a particular species of live oak that grows only about ten feet high. It has blue-green, spine tipped, hollylike leaves. Almost as common is the birch-leaf mountain mahogany,

Joe LeMonnier



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a shrub that—like so many other species with dense wood—is sometimes called ironwood. It is a member of the rose family, but its flowers lack petals. Mule deer browse on it, and its seeds and leaves are a staple in the diet of grouse. Another abundant shrub is desert ceanothus, a five-foot plant with small, thick leaves arranged in opposing pairs on the branchlets. Its small clusters of sweet-scented, white flowers bloom during the summer.

The chaparral contains two types of sumac. Sugar sumac has simple, evergreen leaves; the leaves of the other sumac, called skunkbush, are divided into three leaflets. Skunkbush is one of very few plants in the chaparral that shed their leaves in winter, and as its name suggests, its leaves emit an unpleasant odor when crushed.

One striking shrub is manzanita, whose bright green, thick, oval leaves contrast markedly with its twisted, mahogany-red stems, which glisten in the sunlight. The leaves stand vertically with the edges toward the sun, an adaptation that helps reduce water loss.

Datil, a nonwoody, succulent species, is a type of yucca. The leaves arise from ground level, are about two inches wide, and have fibrous threads that hang from the edges. Datil's white flowers are borne on a stalk up to six feet tall.

One of the most conspicuous chaparral plants, at Diamond Point and elsewhere, is the century plant. This species of agave has clusters of succulent leaves that often are nearly two feet long and up to six inches wide, with spiny teeth along the edges. After forty to sixty years (not one hundred, as the common name implies), a thick green stalk begins to grow upward from the leaves. When the stalk is about fifteen feet tall, it puts forth clusters of attractive yellow flowers. After producing seeds, a process that takes about six months, the plant withers and dies.

The chaparral's fallen leaves are thick and leathery and do not decay readily, creating a fire hazard. In June 1990, a conflagration in Tonto National Forest came within a few miles of Diamond Point. Known as the Dude Fire (named for Dude Creek), it consumed chaparral and woodland over an area three miles wide and fourteen miles long, killed several people, and destroyed fifty-one cabins, including one that belonged to Zane Grey, the legendary writer of western novels.

Most of the chaparral's woody species are well adapted to survive fires, resprouting rapidly from their massive root systems. Most also begin to produce seeds during the first five years of life, rather than later, which is common in many woody plants. The seeds are often fire resistant, and those of some species will germinate only after being subjected to fire. Plants lacking fire-resistant seeds usually produce a very large number of seeds.

Arizona chaparral and Madrean woodlands grow where winters are mild and summers hot. Precipitation at Diamond Point, averaging about eighteen inches annually, falls primarily during two seasons. About 55 percent falls during the winter (from November through April), usually in the form of gentle rains, while another 35 percent drops during intense thunderstorms in July, August, and September. May and June, the early part of the growing season, are usually dry. Where similar conditions prevail, as in the Mazatzal Mountains twenty miles southwest of Diamond Point, a similar selection of chaparral species appears. But a different chaparral community arises in California, 200 miles to the west, where rain falls mostly in winter.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the U. S. national forests and other parklands.

Manzanita frames a century plant into which a few juniper cones have fallen.

Waiting for Comets

by Joe Rao

How long will we have to wait before our skies are visited by a truly spectacular comet—one that we will be able to see with the naked eye, perhaps even during daylight? Not long, if you believe in the law of averages.

In a given year, about a dozen comets with predictable orbits around the sun can be expected to return to the inner solar system. But the vast majority of these periodic visitors (such as Halley's comet) are usually fairly faint. After repeated passes close to the sun, much of the ice on the surface of a comet has been heated, vaporized, and lost. The gas and dust escaping from a comet's relatively small nucleus are what form the long tail that makes it visible to us. Comets with little ice left to vaporize are usually observable only with the aid of a telescope.

There is always a chance, however, that one of the larger, unpredictable comets will surprise us. Instead of having a relatively tight elliptical orbit around the sun, these long-period comets arrive fresh from far beyond the orbit of the known planets. Only this class of comets offers us much hope of seeing a truly brilliant object.

Thirty years ago this month, one of the most brilliant comets seen in modern times appeared in the predawn eastern sky. On September 18, 1965, Kaoru Ikeya, a Japanese piano polisher, and Tsutomu Seki, an astronomer at Japan's Kochi Observatory, independently discovered the new object within fifteen minutes of each other. Initially visible only with a telescope, Comet Ikeya-Seki was described as a "diffuse tailless glow."

By October 20 and 21 of that year, however, favorably placed observers around he world watched the comet become so brilliant that it could be seen with the naked eye in broad daylight; all one had to do was to block out the sun's glare with an outstretched hand.

Ikeya-Seki came fairly close to hitting he sun. On October 21, at perihelion (the moment Ikeya-Seki made its closest approach), it passed within 292,000 miles of the sun's surface—close enough to break the comet's nucleus in two. The Tokyo Observatory described it as appearing "ten times brighter than the full moon."

Comet West, the most recent bright comet, could be seen with the naked eye for about a month after its close approach to the sun on February 25, 1976.

Royal Observatory, Edinburgh; Photo Researchers, Inc.

After perihelion, the comet's tail grew rapidly to nearly 70 million miles in length. During morning twilight in early November, Ikeya-Seki was a majestic sight, rising tail first like a narrow searchlight beam from the southeastern horizon. By mid-November it was no longer visible to the naked eye as it headed out into deep space, perhaps not to return again for nearly a thousand years.

On average, the appearance of such spectacular comets occurs once every twenty to twenty-five years. There have been seven bright comets thus far this century. The last one, Comet West, zipped by the sun in February 1976, so odds are that we are due for another bright comet sometime soon.

The Planets in September

Mercury may be spotted about one-half to three-quarters of an hour after sunset. Scan the horizon with binoculars just south of due west. The best time to try to spot the planet is on the 9th, when Mercury reaches greatest elongation (27° east of the sun).

Venus won't be back until late next month, when it will start to climb slowly into the western sky after sunset.

Mars keeps pace with the sun, setting by the end of evening twilight, some two hours after sundown. But this month it is only magnitude 1. 4, low in the southwest at dusk. In the early evening on the 27th, Mars lies below the crescent moon in the southwest sky.

Jupiter can be found in the southwest at dusk and sets about three hours later. It is the brightest "star" in the sky. The red supergiant star Antares is to its lower left at the start of the month. On the 20th, Jupiter passes 5° north of Antares, the last of its three passes by the star this year. The next triple conjunction between Jupiter and Antares will occur in 2066. The crescent moon will be near Jupiter on the evening of the 1st and again on the evening of the 29th.

Saturn is in Aquarius, rising at about sunset, and is visible for most of the night. Anyone with a medium-size telescope has a chance to see the unusual sight of Saturn's ring system, which now appears only as a thin band of light across the planet. This is the month of this planet's opposition (on the 14th), when Saturn appears at its biggest and brightest (at magnitude 0.7) for 1995. On the night of the 9th/10th, look for the planet well below and to the right of the waning gibbous moon.

The **Moon** is at first quarter on the 2d at 5:03 A.M., EDT; full moon is on the 8th at 11:37 P.M., EDT; last quarter is on the 16th at 5:09 P.M., EDT; and new moon is on the 24th at 12:55 P.M., EDT. The September full moon is also this year's harvest moon, occurring nearest to the autumnal equinox.

The autumnal equinox occurs at 8:13 A.M., EDT, on the 23d. Autumn begins at this moment over the Northern Hemisphere as the sun's direct rays migrate across the equator and into the Southern Hemisphere.

Meteorologist Joe Rao is a guest lecturer at the American Museum-Hayden Planetarium.

Discovery

Recommended travel and reading from the authors of this month's features

Marketplace at Phomsavan, Laos
Jamie James

Venezuela: Birds and Beyond

(Story on page 40)

The Venezuelan llanos, a vast region of savanna bordered by the great Orinoco River, is a land of open vistas, abundant wildlife, cattle ranching, and agriculture. There are generally two seasons: one, rainy from May through October; the other, dry from November through April. The area has become well known to wildlife enthusiasts because several large, private ranches there, most notably El Cedral, El Frío, and Piñero, are open to visitors. Birds, such as the scarlet ibis, yellow-knobbed curassow, jabiru stork, king vulture, and scarlet macaw, are abundant. A few notable wildlife species that can also be seen are jaguar, capybara, anaconda, and spectacled caiman.

To view dickcissels, visitors must travel to the region's agricultural areas. There, most of the wildlife listed above has been extirpated. Dickcissels are present from October through late April at sites near the cities of Calabozo and Acarigua, but chances of locating a megaroost are best near Acarigua, where the Pozo Blanco Environmental Education Center offers the best visitor accommodations.

While there are no official campsites, campers, according to author Gianfranco Basili, "almost always receive a favorable response" when asking local landowners for permission to stay on their property. For the adventurous, Basili recommends finding a campsite near, or even inside, a megaroost. When looking for megaroosts, try to take someone with you who knows the countryside; many of the area's roads are not shown on maps.

Arrangements to see dickcissel megaroosts and other unique areas of the llanos can be made through the Venezuelan Audubon Society in Caracas. (Telephone: 58-2-923-268)

A good source of additional information on birding in the Venezuelan llanos is Steven Hilty's "Birding the Venezuelan Llanos," which appeared in the fall 1992 issue of *American Birds* magazine.

Morning flight of dickcissels, Venezuela
Gianfranco Basili

Laos's Plain of Jars

(Story on page 48)

Visitors to Laos must first fly into its capital, Vientiane, a small, graceful city with temples, museums, and a market. From there, excursions can be arranged to the Plain of Jars.

Flights to Phomsavan, the capital of Xieng Khouang Province and the town nearest the main jar site at Ban Ang, are scheduled almost daily. Flying not only saves visitors a grueling two- to three-day bus ride but also offers expansive views of the countryside. Phomsavan is a small town with one or two very simple restaurants, a weekly market, and a few guest houses.

Other jar sites in the surrounding area include Ban Hin, Ban Soua, and Lat Sen. By bus or rented truck, visitors can also reach the nearby town of Muang Kham, known for its hot springs. A short distance from Muang Kham is Tham Piu, a large cave in a limestone cliff.

Even though the Plain of Jars is not subject to the extremes of wet and dry seasons, much of the rest of Laos is. You may want to avoid the rainy season by going sometime between November and April, although vegetation is lushest during the early and late rainy season. Group tours are the easiest way to see Laos because the government has a complicated system of police passes and permits for travel within the country. A helpful book is *Laos: A Travel Survival Kit,* by Joe Cummings, published by Lonely Planet Publications.

Salmon Rivers of the Northwest

(Story on page 26)

Northwest salmon runs are in serious decline today, but some remain strong, and good viewing spots still exist throughout the Pacific Northwest. In some of the best places, conservation societies also provide educational programming designed to include visitors in helping to save the salmon and its environment. The best times of the year to view salmon runs vary from place to place, so be sure to schedule your trip accordingly.

In Oregon, the Portland fish conservation organization Oregon Trout sponsors "Salmon Watch," an annual, comprehensive, environmental education program for schoolchildren from the Portland and Eugene areas (for information call 503-222-9091). Salmon Watch field trips, which focus on the Columbia River Basin, include Native American storytelling, water-quality monitoring, spawning surveys, and stream mapping. Washington and Idaho are developing similar Salmon Watch programs.

For information on salmon-related activities in Washington State, contact the Save Our Wild Salmon Coalition in Seattle (206-622-2904). Representatives will help arrange field trips to in-state spawning sites, including those at the mouth of Bacon Creek, in the Park Slough Spawning Channels, and at Issaquah Creek. They also provide a Citizen Action Kit, to let you know what you can do to help save salmon.

Visitors to Seattle can also view an exhibit called "Reaching Home: Pacific Salmon, Pacific People," featuring photographs and text by Natalie B. Fobes, photographer for this issue's salmon article. A documentation of the life cycle of wild salmon, the exhibit is on display at the University of Washington's Burke Museum until February 4, 1996. For more information, call (206) 543-5665.

With two acres of formal gardens and orchards and twenty acres of woods, streams, and trails, the Haig-Brown House (604-286-6646), located on the banks of the Campbell River in British Columbia's Vancouver Island, is a great place for an educational family vacation. This former home of conservationist and nature writer Roderick Haig-Brown offers bed-and-breakfast accommodations plus "Natural History and Fisheries Enhancement Tours." These include field trips to the Campbell's natural chum salmon spawning channels and to new, artificial chinook spawning grounds.

"For the first time, we're also offering river swims with the salmon," says site manager Kevin Brown. "After all, Haig-Brown was the first person ever to snorkel down the Campbell River."

A *Yakama Indian gaffs a chinook salmon on the Columbia River.*

latalie B. Fobes

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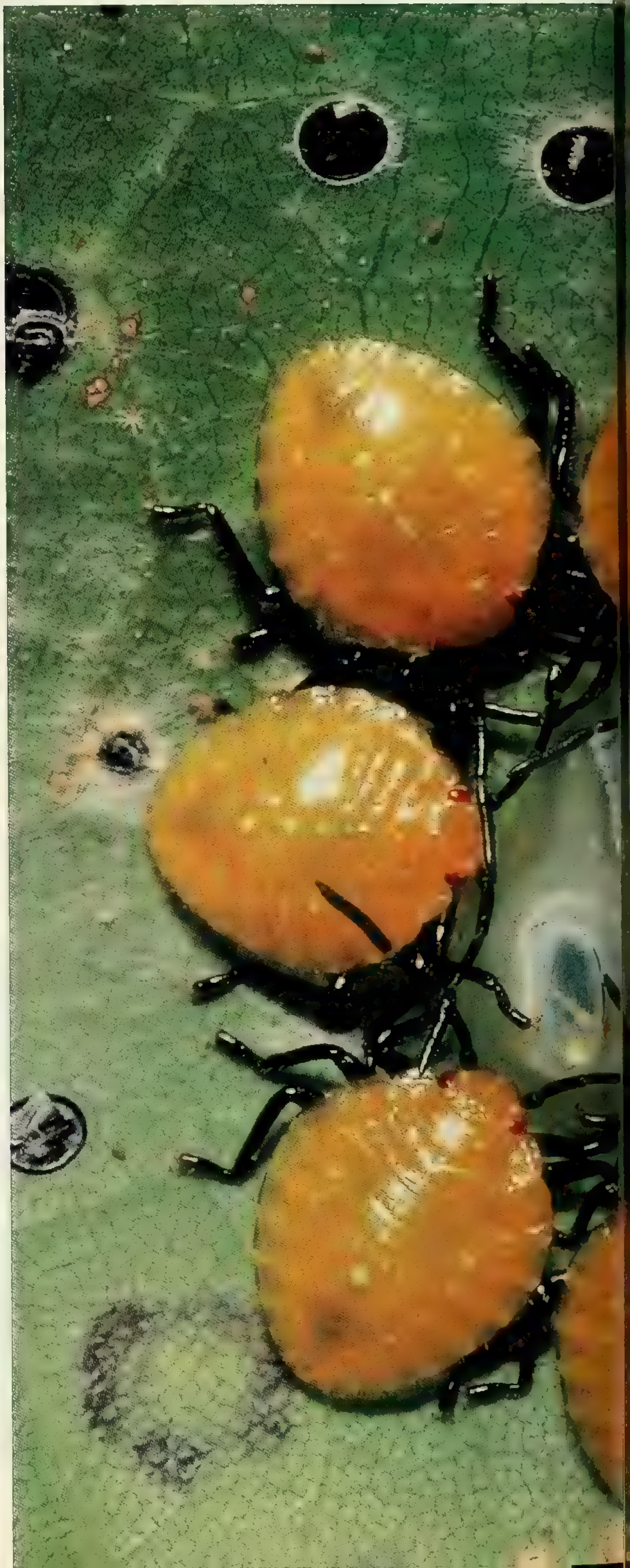
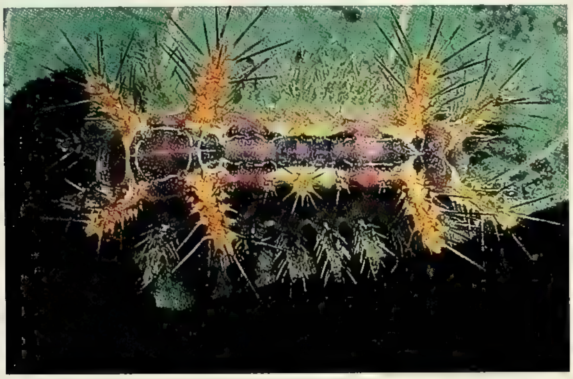
Impressive Lineup

Why are these newly hatched stinkbug nymphs, of the family Pentatomidae, neatly lined up around their empty eggshells? When photographer Ken Preston-Mafham noticed them on a low-lying bush near the Peruvian town of Tíngo María, he was struck by the aggregation's resemblance to the slug-moth caterpillar (below), whose spines deliver painful stings.



Some entomologists believe that the tiny nymphs, each about twice the size of a pinhead, have evolved this behavior to fool hungry birds and monkeys into leaving them alone. Such mimicry, in which harmless insects have evolved the appearance of a poisonous or stinging species, is common in the rain forest. When they sense a mammal's or bird's warm breath, stinkbugs kick their legs in the air and wave their antennae; the resultant Busby Berkeley effect resembles the bristling of a slug-moth caterpillar's poisonous spines. Since the caterpillars often stay still for long periods, the bugs' inability to move forward as a group does not compromise the illusion.



Mature stinkbugs, as their name suggests, can secrete a malodorous chemical from a gland in their abdomens. Many species are easily identified by their bright colors, especially in flight; a common South American stinkbug has bright bluish green wings, black and yellow stripes on its underbelly, and red legs. In a number of species, females protect the young, sometimes performing headstands while buzzing their wings at any intruder. The species shown, however, does not benefit from such maternal care, and the young are left to their own devices. Since their chemical weaponry is not yet well developed, the nymphs appear to use group mimicry at this vulnerable stage of their lives.—*Richard Milner*

Photographs by
Ken Preston-Mafham
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AUTHORS

Primatologist **Meredith Small** ("Rethinking Human Nature—Again") is an associate professor of anthropology at Cornell University whose special research interest is female mate choice and sexual behavior. Her most recent book is *What's Love Got to Do With It? The Evolution of Human Mating* (Doubleday/Anchor Books, 1995). Small's previous articles for *Natural History* were "Ms. Monkey" (January 1989) and "Macaque See, Macaque Do," (March 1994).

The study of the grassland birds known as dickcissels, conducted by **Gianfranco Basili** and **Stanley A. Temple** ("A Perilous Migration") is one of the few to follow a single species throughout its annual cycle on two continents. A doctoral candidate in wildlife ecology at the University of Wisconsin, Basili became interested in the birds when he "accidentally" came upon huge flocks of them while studying raptors on the Venezuelan llanos. The chance sighting developed into a four-year study of the imperiled dickcissels.

Coauthor Stanley Temple, Beers-Bascom Professor in Conservation at the University of Wisconsin, has researched neotropical migrants since 1975. A falconer since the age of twelve, Temple has worked with some of the rarest birds in the world, none of which has yet become extinct. He hopes his "success continues with dickcissels."

Richard Dawkins ("The Evolved Imagination") was educated at Oxford, where he studied under the Nobel Prize-winning ethologist Niko Tinbergen. Author of *The Selfish Gene* (Oxford University Press, 2d ed., 1990) and *The Blind Watchmaker* (Norton, 1986), Dawkins has been a lecturer in zoology at Oxford since 1970. His latest book is *River Out of Eden: A Darwinian View of Life* (Basic Books, 1995).

Paul Kerlinger ("Night Flight") has been interested in bird flight since his graduate school days in the 1970s, when he first studied hawk migration. From 1987 to 1994, Kerlinger served as director of the New Jersey Audubon Society's Cape May Bird Observatory. Now an environmental consultant based in New York City, he is the author of *How Birds Migrate,* just published by Stackpole Books.

Photographer, author, and amateur entomologist, **Ken Preston-Mafham** ("Impressive Lineup") has traveled to more than thirty countries to photograph wildlife. His picture of the stinkbugs, captured with a Nikon F2 with a 55 mm macro lens and a single small flash, was taken during a three-month stay in a Peruvian forest. He is now in Uganda working on a BBC television documentary on insects and spiders. Preston-Mafham is the author of the *Encyclopedia of Land Invertebrate Behaviour* (MIT Press, 1993).

Jessica Maxwell ("Swimming with almon") is a columnist for *Audubon* nagazine and a regular contributor to *squire*. Her book on the plight of Pacific almon, *The Salmon Circle*, will be ublished by HarperCollins in 1996. Maxwell lives on an island in Puget ound and is at work on a book about fly ishing.

Natalie B. Fobes's photographs and ature articles have appeared in *National eographic, Geo, Audubon, US News nd World Report,* and *Forbes*. Her book *eaching Home: Pacific Salmon, Pacific eople* (Alaska Northwest Books, 1994) s in its second hardcover edition. Fobes ives in Seattle.

Russell Ciochon (left) and **Jamie ames** ("Laos Keeps Its Urns") have raveled extensively throughout Southeast sia, exploring paleontological and rcheological sites and forging contacts vith Asian scholars. They are currently ompleting work on a book about the egion's archeology for Oxford Jniversity Press. A previous collaboraion with archeologist John Olsen esulted in *Other Origins: The Search for he Giant Ape in Human Prehistory* Bantam Books, 1990), which details a ietnam expedition. Ciochon is an ssociate professor of anthropology at the Jniversity of Iowa. James, who writes rimarily about archeology and the arts, the author of *The Music of the Spheres: lusic, Science and the Natural Order of e Universe* (Grove Press, 1993).

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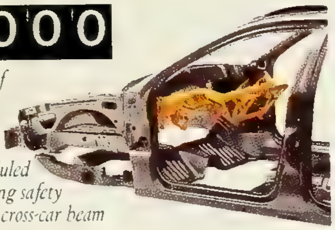

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Cover: In Benin, West Africa, a devotee of Vodun carries wooden figures representing dead twins tucked in her dress. Story on page 40. *Photograph by Henning Christoph; Das Fotoarchiv*

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Sweating the Details

"The Smart Gorilla's Recipe Book" (page 12) is a brief article and seemingly straightforward enough: Effie, a mountain gorilla, eats a nettle-coated leaf by first rolling it in her fingers so that the spines won't pierce her tongue. Effie can perform the manipulation more easily than we can describe it, and reading through the action in stop-action reminded me of those old Disney television shows, when Walt would walk us behind the scenes for a look over the animator's shoulder. There, we were shown that it might take a hundred different drawings to animate a wave of Snow White's hand; that what brought every character to life was an astonishing accumulation of detail. This is just how good field studies, and stories, come to be.

A hatchling monitor lizard tackles a grasshopper in Namibia.
John A. Phillips

Between 1869 and 1909, Alfred Brown, a British-born South African schoolmaster, postmaster, and librarian, spent the better part of his days and his salary trying to follow every movement of the fifteen-pound, five-and-a-half-foot monitor lizards that roamed the rugged terrain of Brown's frontier outpost northeast of Cape Town. While Brown died without putting together the pieces of his studies, eighty years later John A. Phillips (page 50), using electronic technology not available to Brown, was able to track the lizards on their long migrations and put together the details of their lives. What these details tell him is that the monitors are a bigger part of the bigger picture than anyone knew. The total mass of the 9,000 lizards in the protected lands of Etosha National Park rivals the mass of the park's lions. The same is not true outside the park, where the skin and pet trades have decimated the lizard population.

Why do hammerhead sharks school where they do? In "Hammerhead City" (page 32), A. Peter Klimley tells how working out the details over fifteen years of studying these animals—even swimming with them—finally allowed him to get a look at the sharks' world as sharks see it. Only then could he put together their story for us.

While studying the Vodun sculptures of Benin, in southwest Africa, researcher Suzanne Preston Blier (page 40) realized that the belief that the gods dwell everywhere and animate every aspect of life not only inspired Vodun art but also helped shape it. The art had to be made of just the right materials, and in just the right proportions, to affect the spiritual world. Get the details right—of the art, the dance, the ritual—and the gods will get the message.

"We understand generalities best by focusing on the details of particulars," writes Stephen Jay Gould in his essay this month. Just so, we bring you behind the scenes for an intimate look at the details that animate every aspect of natural history.—*Bruce Stutz*

A child in Benin watches a Vodun ritual from the sidelines.
Henning Christoph; Das Fotoarchiv

"The earth's climate is like a giant puzzle, and the polar regions hold many of the clues."

Dr. Monica Kristensen

On the white expanse of Antarctica's Filchner Ice Shelf, glaciologist Dr. Monica Kristensen watches as members of her team remove a ten-meter core sample from the ice. "By studying the different layers, we can see how the climate has varied and carbon dioxide levels have changed over the past few hundred years," she says.

The global warming trend caused by a rise in carbon dioxide and other greenhouse gases is among Dr. Kristensen's most pressing concerns. Many scientists fear that the increases in temperature brought about by such a rise will eventually cause the polar ice caps to start melting, raising sea levels everywhere.

"It's difficult to get the public to focus on something that may not become a problem for a few hundred years," she says. "So my mission right now is to increase public awareness. People need to realize that the polar regions are an important part of the earth's climate system. What happens there will affect all of us."

Her research often takes her to desolate stretches of the Antarctic, where she must remain for months at a time. Says Dr. Kristensen, "Because the conditions here are harsh, my equipment has to be as tough and reliable as my Rolex."

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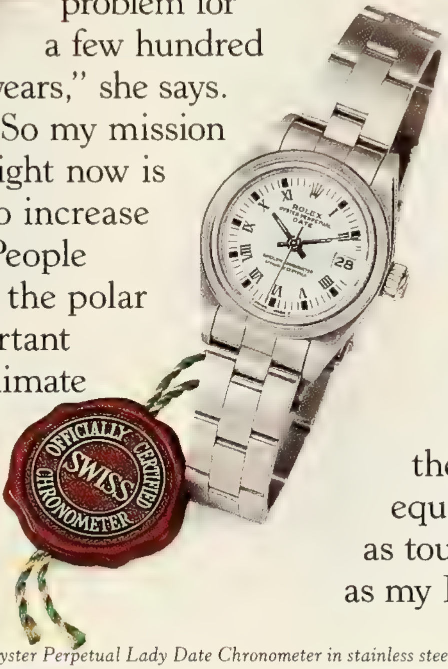

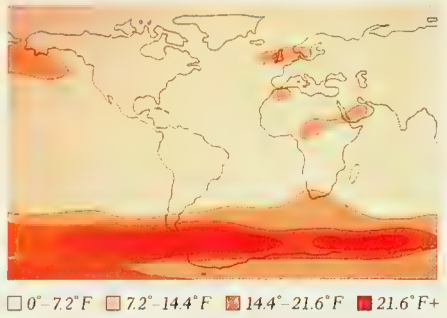

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AUTHORS

Michael A. Taylor ("Fossils by the Sea") first met fossil collector Mary Anning in the pages of the *Children's Encyclopaedia* when he was six. A curator of vertebrate paleontology at the National Museums of Scotland in Edinburgh, Taylor studies the biology of extinct marine reptiles as well as the history of museums. He finds Victorian museum collections to be rich lodes of marine reptile fossils. Coauthor **Hugh S. Torrens** teaches geology and the history of science at Keele University in England, "as far from the seashore as one can get in Britain," but he grew up on the Dorset coast not far from Anning's Lyme Regis. His future plans include writing a biography of Anning and giving a lecture tour in the United States on her life and career.

When **Richard W. Byrne** ("The Smart Gorilla's Recipe Book") is not teaching at the University of Saint Andrews, in Fife County, Scotland, he is in the field, often accompanied by his wife, Jen. He has worked with baboons in Senegal and South Africa, chimpanzees in Tanzania, and most recently, gorillas in Rwanda. His latest book is *The Thinking Ape: The Evolutionary Origins of Intelligence* (Oxford University Press, 1995).

German photojournalist **Henning Christoph** ("The Place Where Vodun Was Born") has had a long fascination with the arts, cults, and ceremonies of West African peoples. A 1967 graduate of the University of Maryland, where he majored in anthropology and journalism, Christoph has worked for several European and American magazines. The photos in this month's article are drawn from his book *Voodoo* (Benedikt Taschen Verlag, 1995), developed with financial backing from UNESCO. **Suzanne Preston Blier** spent a year living in Benin and studying Vodun. She is a professor of African art and architecture in the Department of Fine Arts at Harvard University. Her most recent book is *African Vodun: Art, Psychology and Power,* published this year by the University of Chicago Press.

A comparative physiologist, **John A. Phillips** ("Rhythms of a Desert Lizard") is deputy director of the Center for the Reproduction of Endangered Species, part of the Zoological Society of San Diego. Most of his research focuses on large lizards, which are often the dominant animals in undisturbed habitats throughout the world. Unfortunately, fewer and fewer undisturbed habitats remain. Phillips likes to imagine a world in which the lizards and all other wildlife were doing so well that there would be no need for his job.

Behavioral ecologist **A. Peter Klimley** ("Hammerhead City"), who specializes in marine animals, is based at the Bodega Marine Laboratory of the University of California at Davis. He says that swimming among schools of hammerheads has fulfilled a childhood fantasy. "I was always fascinated by Jane Goodall's work. I wanted to mingle with animals and become accepted by them, to learn their ways, as she did among chimps. With the hammerheads, that is exactly what I've been doing for fifteen years."

Rod W. Patterson ("Upwardly Mobile") is a herpetologist and a photographer who served for three decades as director of the Transvaal Snake Park in Midrand, South Africa. He tried for years to capture the moment when a bullfrog emerges from dormancy in the red sand of the Kalahari. Patterson has written extensively about the breeding of captive reptiles and is the author of *Snakes* and *Reptiles of Southern Africa,* both published by Struik.

Melvin Van Peebles ("Rascals, Survivors, Dreamers") has written and directed five feature films and three Broadway musicals and is the author of thirteen books. He has also been involved with "the Boy Scouts, the Strategic Air Command, the merchant marine, the post office, Het Nederlandes Comedie, the Harkness Ballet, the ACLU, Cinématique Française, Boston marathons, pinochle, Senegalese police, various immigration authorities and the block, blues, and dues."

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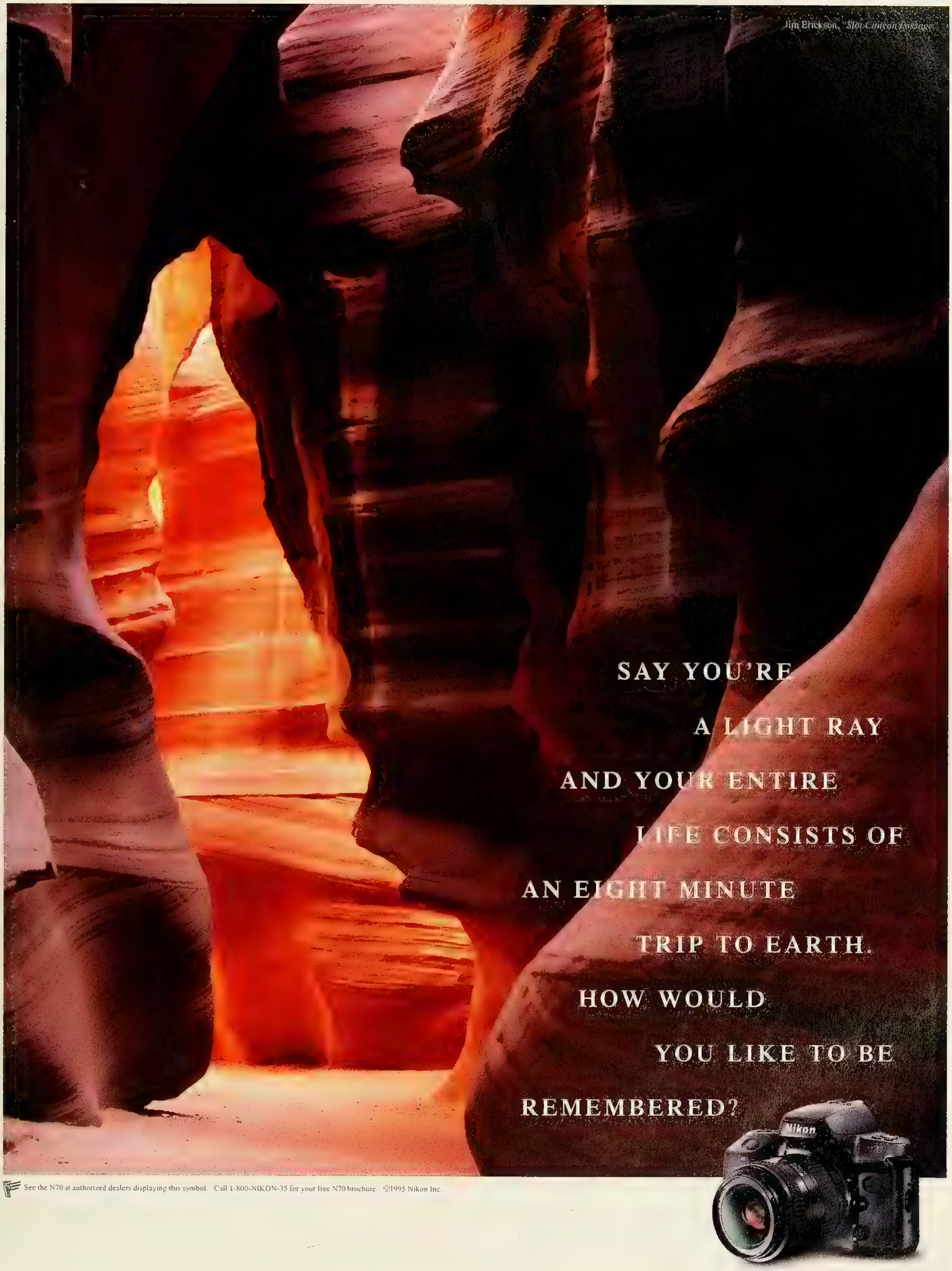
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An Easterbrook Donnybrook

Your August 1995 issue contained two attacks on my book *A Moment on the Earth* from reviewers stridently accusing me of errors, illogic, and other sins ("When Nature Writers Get It Wrong," by Jack C. Schultz and "Denial in the Fortress," by David W. Orr). Both your reviewers themselves employed numerous factual errors, adulterated quotations, or outright falsehoods.

David Orr misrepresents my work by selectively dropping words from quotes. For example, he asserts that I say global warming "is probably in society's interest," making me seem a crackpot. Here is how *A Moment on the Earth* actually reads in the quoted sentence (p. 301): "Mild warming is probably in society's interest." Orr conveniently excises the key word "mild." Even the Intergovernmental Panel on Climate Change has said that *mild* global warming may be of benefit, primarily to agriculture. Following page 301, I discuss the reasons to fear that warming may not stay mild. Yet after altering the meaning of my "society's interest" sentence, Orr then calls me inconsistent for concluding my global warming chapter by saying that the greenhouse effect is a great danger. There is no inconsistency in the book—only in Orr's review.

Your second review of my book, by Jack Schultz, contains many assertions that are false as matters of fact, not opinion. For instance, Schultz asserts that I "caricatured" environmentalists as ones who "hate other humans." The book contains no such statement, but does spend a full page (p. 480) specifically *refuting* the notion that environmentalists are anti-people. Page 480 notes, "A certain percentage of people of all stripes develop intense dislike for their fellow women and men; greens are no more likely to suffer this character defect than any other group."

Schultz asserts that I call human-caused extinctions both "trivial" and "justifiable under natural law." This is a simple lie. The book contains no sentence or section advancing the view Schultz claims. The book does, however, say that ecorealists "ought to support strengthening of the [Endangered Species] act," (Preface, p. xx); that society should devote "ever more of its resources to the preservation of species and habitats" (p. 102), that "species loss is a priority concern of ecorealism" (p. 552), that "all environmental errors are reversible save one: extinction. Therefore the prevention of extinctions is a priority" (p. 649).

According to Schultz, *A Moment on the Earth* says that advocacy of population stabilization is "self-centered, but the desire to sacrifice endangered species for personal gain is not." First, I spend an entire chapter (pp. 473–91) arguing *in favor* of population stabilization. Second, no sentence or section anywhere in the book advocates the "sacrifice" of endangered species for "personal gain." Page 442 rejects "taking" compensation in endangered species cases, noting that a common social interest in conservation has long been recognized by courts as outweighing certain private property rights. Here as above, Schultz has simply fabricated claims regarding the content of the book.

Schultz further says that *A Moment on the Earth* fails to "acknowledge . . . the hundreds or thousands of lives lost to poor, armed people in any of our crowded American cities." Here, from page 333 of the book, "Stepping over the homeless on subway grates, taking detours to avoid the parts of town where schoolchildren die in drug shootouts, Americans are dreaming if they think capitalism is anything other than a transition phase in pursuit of some method of economic organization that insures the well-being of all members of society."

Finally, Schultz makes the preposterous claim that my book's "final paragraphs proposed inserting religious (Christian) values into environmentalism," which he then denounces. I haven't the foggiest idea what he's talking about, and neither will anyone else who reads the paragraphs, or for that matter, who reads any of the four-chapter concluding section of the book. Thus, three times in his review, Schultz fabricates claims about the content of my book.

In closing, I wonder what it is about the idea of environmental optimism that your reviewers found so threatening that they were inspired to use altered quotes and ad hominem language to assail *A Moment on the Earth,* rather than simply engaging its thesis? In rhetoric, debaters usually switch to false claims and ad hominem attacks when they want to divert attention from the substance of someone else's point of view.

GREGG EASTERBROOK
Arlington, Virginia

DAVID ORR REPLIES: Gregg Easterbrook asserts that my review misrepresents his views on global warming by dropping the world "mild" from one quote, "making [him] seem a crackpot." I did not intend to make Mr. Easterbrook appear to be a crackpot. The fact is, however, that his discussions of climate change and other issues are confused. On climatic change, Easterbrook, as I noted, argues on both sides of the issue, but his summary judgment is the soothing conclusion that "probably the problem is nowhere near as distressing as assumed" (p. 308). Moreover, his discussion of global warming is colored both by his earlier portrayal of the earth as a "fortress" impervious to human mismanagement, and by the tone of *A Moment on the Earth,* which is disparaging toward those he calls "enviros" and those suffering "greenhouse anxiety" (p. 35), including many reputable scientists who are less sanguine than he.

Second, regarding Mr. Easterbrook's "environmental optimism," I must say that any view that does not deal adequately with issues of politics, ethics, and ecological limits is not characterized by optimism but by wishful thinking—a different thing altogether.

JACK SCHULTZ REPLIES: When Easterbrook provides quotes, it is indeed true that he wrote those things. However, as I noted in my review, for every direction the book takes, it takes an equal and opposite direction. Easterbrook does not spend page 480 as he thinks he does. With regard to the "character defects" of enviros, page 480 states that "the green movement does contain a puzzling antipathy toward its own genus. . . ." And this is followed by four pages of support for this view in a section titled "Do Enviros Hate People?" Statements like ". . . in the end the desire to control human numbers so that areas of the Earth might remain bereft of people is not

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a modest urge, but a self-centered one" (p. 481) certainly lead me to one conclusion. So do the many innuendoes in this section, such as, "But then the animals are worth more than the people, *n'est-ce pas?*" in a paragraph suggesting an economic motivation for preservationism (p. 482).

It's difficult to assume he is bemusedly observing a constructive movement when one reads, "Perhaps orthodox enviros are fond of top-chain predators such as grizzlies because they are the sole animals capable of killing people. That makes them noble, provided the victim is SOMEBODY ELSE." (p. 681).

Are human-caused extinctions "trivial"? Chapter 2 ("The Green Fortress") appears to me designed to make that and related points about the inconsequential nature of human actions compared with major geological and other events. As I pointed out in my review, Easterbrook again inserts the occasional palliative, warning us not to assume that he is trivializing our impact on the environment, but I doubt that any reasonably careful reader could conclude otherwise: ". . . even the worst-case estimate for human greenhouse malfeasance seems minor by nature's standards" (p. 32). Or "Should this hypothesis prove out it would mean the biosphere that some environmentalists today contend cannot resist so much as an oil spill or an overzealous crew of loggers has in the past survived the unimaginable multiple whammy of the atmosphere set on fire by a killer rock strike . . ." (followed by four other catastrophes on page 33). Perhaps Easterbrook doesn't realize it, but this is trivialization, and all the disclaimers add up to considerably less than the disclaimed polemic.

Easterbrook's concern about "stepping over the homeless" (p. 333) is admirable; he even blames capitalism. However, blaming the loss of Indian villagers to tigers on "orthodox environmentalism" (p. 483) oversimplifies that situation and pits value systems against one another unnecessarily. Both problems have their roots in population density. His concern for species preservation is also admirable, but it is narrowly defined. Easterbrook's "Ecorealist Manifesto" states: "People may not sit above animals and plants in any metaphysical sense, but *clearly are superior in their placement in the natural order.* Decent *material* conditions must be provided for all of the former *before there can be long-term assurance of protection for the latter*" (p. 649; emphases mine).

I'll admit freely that I'm out of my depth in religion and philosophy, but that "placement" of humans in the natural order strikes me as Judeo-Christian; it certainly isn't consistent with some other world religions. It is a way of looking at the world that many evolutionary biologists and other scientists cannot accept logically (or emotionally). He does devote chapter 9 ("Does Nature Have a God?") to reviewing and revising more classical "dominion"-based approaches to understanding our relationship with nature. But as I've pointed out, Easterbrook's vision of future environmental harmony, with its acceptance of a wide range of anthropogenic impacts on the environment, and the meeting of human material needs before worrying about nature's state, all strike me as old-fashioned dominion. As he argues in his final few paragraphs, if nature lacks meaning, humans can create meaning; that's one definition of religion, and I prefer to leave it out of the debate. Humans have also created quite a mess during their moment on the earth. Unlike Mr. Easterbrook, I suspect that moment is like no other.

A Little Exception

Although I do it reluctantly, I must call to the attention of readers of *Natural History* magazine several misstatements made by Professor Jack C. Schultz in his review of my book, *The Dying of the Trees* ("When Nature Writers Get It Wrong," August 1995).

One can perhaps overlook his dismissive description of the book as "eight short chapters," which a brief glance at the table of contents will prove inaccurate. But one must not let go unanswered his claim that no "refereed publication nor a balanced scientific treatment is referred to in the book's pages." Such citations can be found. All eleven chapters are documented with numerous citations of refereed sources.

Professor Schultz further calls into question the considered judgments of such internationally recognized figures as Orie L. Loucks of Miami University, Hubert Vogelmann of the University of Vermont, Robert Bruck of North Carolina State University, and Paul Miller and Douglas Fox of the U.S. Forest Service, among others—all of whom I interviewed (and quote) at length. These scientists need no defense as persons with distinguished professional careers dedicated to impartial investigation into the health of our trees and forests. They are exactly the kind of experts one looks to for understanding the complex nature of forest health.

As one who has reviewed many books written by others, I know that assessing the validity of sources presents no difficulty. Accordingly, I urge readers of your magazine to see for themselves what my sources are, and then to draw their own conclusions about whether *The Dying of the Trees* was accurately described and assessed with some degree of fairness.

CHARLES E. LITTLE
Placitas, New Mexico

JACK SCHULTZ REPLIES: As a forest ecologist and tree lover, my juices started flowing when I read Mr. Little's essays—so much so that I evidently misstated the number of chapters in his book, for which I apologize. But when one topic on which my own work focuses, the gypsy moth, was rolled into the grand scheme of human evil, I began to wonder at the reliability of other relationships. So I went to the refereed literature and to experts who publish there frequently and currently.

Mr. Little's point is that something is terribly wrong with the majority of our forests, and that the cause is anthropogenic. Like the majority of the scientific community, what refereed publications say is that when we observe forest decline, there are often multiple causes, many of which remain to be identified. My reading of that literature and conversations with experts who publish there tell me that there is much less consensus on the role of anthropogenic agents than Mr. Little would have us believe.

The experts made it abundantly clear to me that although Little is sometimes right (as I noted in my review), he is often incorrect; most importantly, considering the wealth of published data available, he doesn't make it clear when no one knows the answers.

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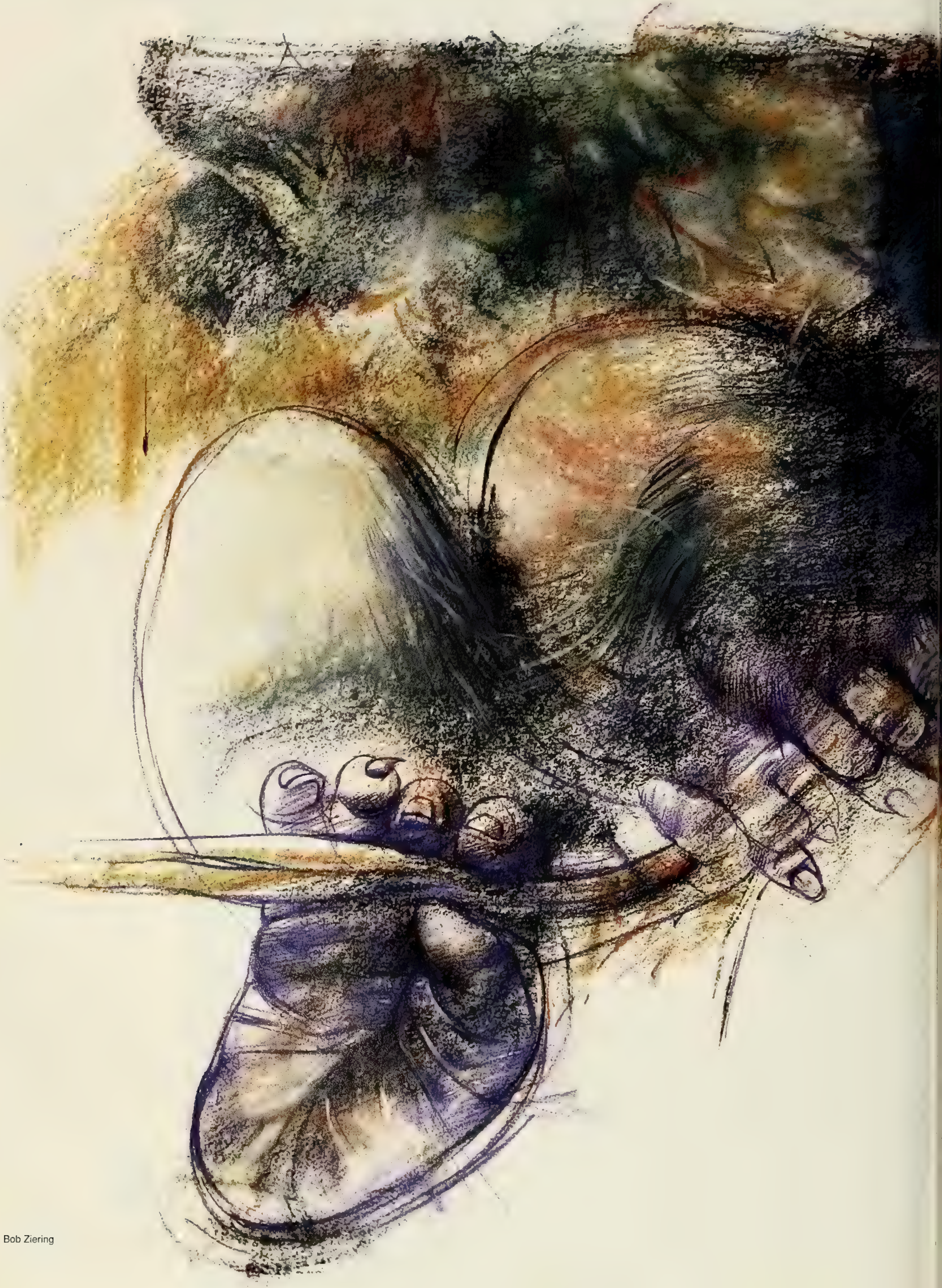

Bob Ziering

The Smart Gorilla's Recipe Book

by Richard W. Byrne

Effie looks determined as she makes a beeline for a tall, tempting nettle clump in the meadow of giant herbs. She gives adolescent Shinda a warning cough of aggression—although he had made no move toward the nettles. (Gorillas are quite antisocial when feeding; they often charged my wife, Jennifer, and me in the early days of our research, until they realized that, although we might keep looking at their choicest morsels, we never ate them.) Reaching the nettle clump, Effie sits down to eat a few handfuls of leaves. Her movements are fast and deft, and we have to look closely to see all the details. Pinching the unfolding leaves at the tip of a stem in her right hand, she pulls the stem into range, and cups her left hand around the stem base. Supporting the roots in the soft earth with her right hand, she sweeps her left hand up the stem. This strips off the leaves, which lie in a whorl in her half-open hand, with the leaf blades protruding but the petioles (leafstalks) lying inside her hand. Gripping the leaf blades in her right hand, she rocks her two fists against each other, tearing off and dropping the petioles. Now she is holding a bundle of nettle leaf blades in her right hand. Deftly adjusting her grip so that she can firmly hold the destalked blades in her right hand without restricting her thumb and index finger for action, she repeats the whole stripping and tearing process on two more stems. Then, carefully opening her right hand, she uses her left hand to delicately pick out a few bits of dead leaf from her enlarged bundle of nettle blades. Finally—and it took us many close observations before we could make out these details—she lifts up the leaf blades with her left hand, folds them down over her right thumb, and then uses this digit to hold the nettle package secure as she pops it through her open lips.

Why should a gorilla bother with such a complicated feeding procedure? Most gorillas live in moist tropical forests where leaves are inedible, protected by poisonous compounds and strengthened by the indigestible, organic substance lignin; but gorillas of the Virunga Volcanoes in Rwanda and Zaire live in mountain meadows, on the densely vegetated flanks of the craters. Here, many leaves are edible but fruit is scarce. Like chimpanzees—and ourselves—gorillas have simple stomachs, unable to neutralize plant poisons or otherwise deal with tough leaves. Thus, over most of the species' range, gorillas eat ripe fruit, rich in energy but poor in nutrients such as protein and trace elements. And like chimpanzees, they make up these dietary inadequacies with supplements—insects, buds, flowers, fungus, and bark.

So what is a fruit-specialist ape doing in mountain meadows? We believe that's where the fancy fingerwork comes in. Many mountain herbs are lettucelike in chemical composition, free of lignin and poisons and rich in protein, but that doesn't mean they are simple to eat. Take the nettle. The plant is defended physically by powerful and unpleasant stings. To understand the secret of Effie's technique, we first need to understand stings. Nettle stings are most numerous on the stem and on the leaf petioles and edges; leaf undersides are less defended. Mature stings are triggered, like a trap, by a gentle touch. Thus, a firm grip is the best approach. On new leaves, the stings haven't yet developed, so Effie's firm pinch on the soft leaves at the tip is quite safe.

In stripping off the leaves from the stem—her next action—her hand contacts only the leaf undersides, the least stinging part. The petioles are covered with stinging hairs, but Effie's firm grip, as she tears them off, again minimizes the stings' effects. After carefully picking out any inedible debris, Effie is left with the problem of what to do with the stinging edges of the protruding bundles of leaves—hence that neat little fold, producing a parcel in which the stings are wrapped in the least offensive part of the plant, the leaves' undersides. Once crushed in the mouth, stings are ineffective. Although Effie is the highest ranked female in her group, she's not alone in her skill. We found that all adult and juvenile gorillas in these mountain meadows dexterously follow this complex sequence of actions to remove or neutralize all the nettle's defenses.

Gorillas eat other things besides nettles, and they employ a range of techniques, each neatly suited to a particular mountain herb's defenses. With thistles, which have sharp spines instead of stings, firm pinching doesn't work; thistles must be eaten with the spines outward to avoid pricking the mouth. The long stem is collapsed by bending it first one way, then the other. As a result, prickles on consecutive handfuls face in opposite directions, and the gorillas eat handfuls alternately left and right so they don't have to swing the unwieldy and prickly stem around.

Wild celery is another source of food; its edible pith is encased in a hard outer skin that must be removed without destroying the soft contents. Lacking prickles, the stem is quickly chopped or bitten into manageable lengths by a gorilla. Then the hard casing is removed, using the incisor teeth like a workman's pincers, until at last the pith is exposed.

Bedstraw, or what the Scots call sticky Willie, has tiny hooks that cover the plant, helping it to clamber over other vegetation—but also making it difficult to eat. The gorillas' trick for bedstraw is to wind up the trailing stems into a compact mass, roll the mass tightly into a ball against the chin, and slice it with shearing bites—just like chopping herbs with a knife.

These four plants make up 85 percent of Effie's diet and explain the mystery of how gorillas manage to live in the Virunga Volcanoes where no fleshy fruits grow. Manual aptitude has enabled the gorilla to colonize a most unusual place by means of a diet otherwise available only to hoofed animals, whose complex stomachs (or in the case of elephants, very large intestines) enable bacterial action to deal with plants' unpleasant physical defenses.

Can we call this aptitude "intelligence"? The gorillas' plant-preparation talents are no doubt dependent on their prehensile hands, hands made more dexterous by the extensive cortical areas of the brain devoted to delicate control of finger movements. Manual precision alone would suffice for single actions, but the techniques are also organizationally complex. To do the job, all the actions must be correctly sequenced. Coordination is essential between the two hands acting in different roles. And some patterns of actions are repeated or used in other techniques—in what computer programmers call subroutines.

As a psychologist my interest is in the evolution of human intelligence, so I get excited about any intelligent-seeming behavior in great apes. Our gorillas' feeding skills can provide insight into the origins of human aptitudes. The natural ability to learn complex, organized skills may not be unique to humans and may date from an early evolutionary stage, before the separation of the lines leading to modern gorillas, chimpanzees, and ourselves. For most other animals, even monkeys, the only organization shown in their learned actions is that imposed by environmental constraints, not by their minds.

Humans do impose structure on their learned behavior, while remaining sensitive to environmental demands. Our actions in the kitchen provide a commonplace example. When we use recipes for cooking, the details—how thick to slice, how hard to whip, the exact type of tomato or pepper to use—can vary, but the overall program, the recipe itself with the correct order of steps, cannot. The complex techniques gorillas use in plant preparation for feeding are recipes in this sense. Natural selection has equipped many animals with innate recipes to organize their actions, like the elaborate nest-construction methods of birds and some social insects. Written into each individual's genes, these recipes do not depend on learning for their organization. What is special about the gorilla's recipes is that they are learned. To build up such a coordinated plan of many different and detailed actions requires what scientists call a working memory to integrate the pieces. Our everyday behavior depends for efficiency on our remembered recipes, or scripts—how we greet people, use computers, cook supper, or shop. That mountain gorillas have this same recipelike behavior suggests that the mental apparatus we use in these skills predates language.

The case is strengthened by related behaviors of chimpanzees, whose insect-catching and nut-cracking methods with tools are techniques comparable in organizational complexity to the gorilla's plant-feeding skills. Chimpanzees also make tools out of objects (*see* "Dim Forest, Bright Chimps," *Natural History,* September 1991). Pygmy chimpanzees, although not toolmakers in the wild, have shown great facility in captivity.

We are keen to find out how our mountain gorilla group learned their complex techniques. Our work thus far has shown that the answer seems to involve both trial and error and observation of skilled practitioners. (Our research was interrupted by the political turmoil in Rwanda and Zaire.) In contrast to what we might expect from the human perspective, the closest thing we've seen to anything that can be called "teaching" is when mothers sometimes deliberately remove inedible plants from the hands or mouths of infants. (Chimpanzees are the only other species of animals observed doing this.)

Mother gorillas also remove food plants that have defenses that the infant cannot yet deal with. Apparently, gorillas can anticipate the possible consequences of their babies' actions. However, they certainly do not learn everything through blow-by-blow imitation, because each individual gorilla has a different, preferred set of variants for each stage of a process. This implies that each animal has learned the actions by trial-and-error exploration, not by imitation.

Yet the overall program of actions hardly ever varies—except for right-handers and left-handers doing the mirror image of one another—even though the five or six component processes can be ordered in numerous other ways, many of which are sufficient for preparing their food. We believe that a young gorilla imitates its mother in the overall form of the program—its sequence of actions, subroutines, and hand coordinations. The precise details are then "fleshed out" by individual experience, an efficient method when exactness is not too important.

The ability to learn in this way is crucial to human apprenticeship and crafts and may be unique to the great apes and ourselves—great apes possess some of the mental apparatus that humans put to use so effectively in planning, language, technology, and thought. This includes a working memory in which to assemble and execute recipelike programs of actions, aided perhaps by watching how others organize their actions. When we observe old Effie dealing with some evil-looking nettles with her usual efficiency, we may be looking at one of the precursors of human thought.

Richard W. Byrne works in the Scottish Primate Research Group of the University of Saint Andrews, in Fife County, Scotland. His most recent book is The Thinking Ape: The Evolutionary Origins of Intelligence *(Oxford University Press, 1995).*

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The *Great Western* and *The Fighting* Temeraire

A tale of two ships, a master engineer, and a painter of masterpieces

by Stephen Jay Gould

Science progresses; art changes. Scientists are interchangeable and anonymous before their universal achievements; artists are idiosyncratic and necessary creators of their unique masterpieces. If Copernicus and Galileo had never lived, the earth would still revolve around the sun, and earthlings would have learned this natural truth in due time. If Michelangelo had never lived, the Sistine Chapel might still have a painted vault, but the history of art would be different and humanity would be a good deal poorer. This "standard" account of the differences between art and science belongs to our distressing but prevalent genre of grossly oversimplified dichotomies—stark contrasts that both enlighten in their boldness and distort in their formulaic divisions of complexly intertwined entities into two strictly separated piles—"and never the twain shall meet, Till Earth and Sky stand presently at God's great Judgment Seat."

The supposed inexorability of technological progress, under this distorting dichotomy, leads to the myth of science as virtually disembodied—a machine endowed with its own momentum, and therefore striding forward almost independently of any human driver. Scientists, under this model, become anonymous and virtually invisible. A few names survive as icons and heroes—Edison and Bell as doers, Darwin and Einstein as thinkers. But if we accept the premise that technological innovation (in manufacturing, warfare, transportation, and communication) has powered social change far beyond all other consequences of human emotion and ingenuity, how can we resolve the paradox that the people most responsible for propelling human history remain so invisible? Who can name anyone connected with the invention of the crossbow, the zipper, the typewriter, the Xerox machine, or the computer?

Artists, politicians, and soldiers win plaudits and notoriety, although so many impose themselves only lightly and transiently upon the motors of social change. Scientists, engineers, and technologists forge history and gain oblivion as a reward—in large part as a consequence of the false belief that individuality has little relevance when a progressive chain of discoveries proceeds in logical and inexorable order. Let me illustrate our different treatment of scientists versus statesmen and artists with two pairings.

Colonel Calverly, head of a company of dragoon guards in Gilbert and Sullivan's *Patience,* introduces his troops by giving the audience a formula for their construction:

> If you want a receipt for that popular
> mystery,
> Known to the world as a heavy
> dragoon,
> Take all the remarkable people in
> history,
> Rattle them off to a popular tune.

The colonel then rips off (at patter-song speed) two hilarious doggerel verses listing thirty-eight historical figures, including a few fictional and general characters. Only one is a scientist. (The notoriously sexist Gilbert listed three times as many women—Queen Anne, the generic and demeaning "odalisque on a divan," and Madame Tussaud, founder of the great London wax museum.) The scientist appears in the first quatrain:

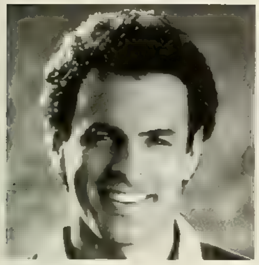
> The pluck of Lord Nelson on board of
> the *Victory*—
> Genius of Bismarck devising a plan—
> The humor of Fielding (which sounds
> contradictory)—
> Coolness of Paget about to trepan.

Most of us will have no trouble with the first three—Admiral Horatio Nelson dying at the battle of Trafalgar, the great German statesman, and the author of *Tom Jones*. But scientists gain little recognition in their own times and quickly fade from later memory. So who is Mr. Paget, about to open his patient's skull? Sir James Paget, surgeon to the queen and a founder of the science of pathology, may have been a household name to his Victorian contemporaries, but few of us know him today (and I couldn't have made the identification without my trusty encyclopedia). So scientists and engineers create history, but Gilbert chooses only one to participate in the construction of English fiber, and even this man has since sunk to oblivion in the general culture of educated people.

For the second pairing, let us return to Admiral Nelson and the story of Trafalgar. On October 21, 1805, Nelson's fleet of twenty-seven ships met and destroyed a combined French and Spanish force of thirty-three vessels off Cape Trafalgar near the Strait of Gibraltar. Nelson's forces captured twenty ships and put 14,000 of the enemy out of commission (about half killed or wounded and half captured), while suffering only 1,500 casualties and losing no ships. This victory ended Napoleon's threat to invade England and

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University. He is also Frederick P. Rose Honorary Curator in Invertebrates at the American Museum of Natural History.

All he really wanted was to stop losing his hair.



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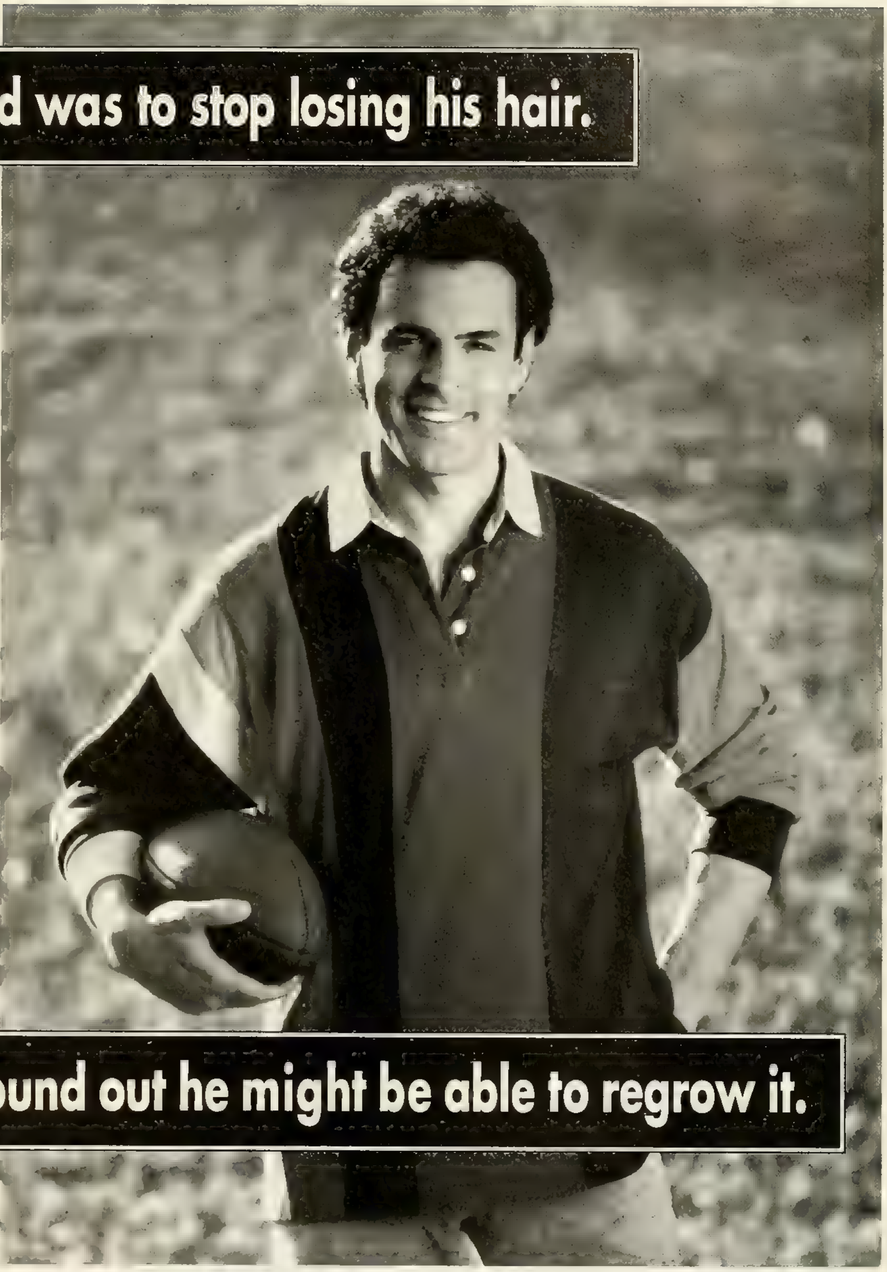

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After 1 year of use, almost half of the men who continued using *Rogaine* rated their regrowth as moderate (40%) to dense (8%). Thirty-six percent reported minimal regrowth. The rest (16%) had no regrowth.

Side effects? About 7% of those who used *Rogaine* had some itching of the scalp. (Roughly 5% of those using a placebo reported the same minor irritations.) *Rogaine* should be applied only to a normal, healthy scalp (not sunburned or irritated).

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See next page for important additional information.

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What is ROGAINE?
ROGAINE Topical Solution is a prescription medicine for use on the scalp that is used to treat a type of hair loss in men and women known as androgenetic alopecia: hair loss of the scalp vertex (top or crown of the head) in men and diffuse hair loss or thinning of the front and top of the scalp in women. ROGAINE is a topical form of minoxidil, for use on the scalp.

How effective is ROGAINE?
In men: Clinical studies with ROGAINE of over 2,300 men with male pattern baldness involving the top (vertex) of the head were conducted by physicians in 27 US medical centers. Based on patient evaluations of regrowth at the end of 4 months, 26% of the patients using ROGAINE had moderate to dense hair regrowth compared with 11% who used a placebo treatment (no active ingredient). No regrowth was reported by 41% of those using ROGAINE and 58% of those using a placebo. By the end of 1 year, 48% of those who continued to use ROGAINE rated their hair growth as moderate or better.
In women: A clinical study of women with hair loss was conducted by doctors in 11 US medical centers. Based on patients' self-ratings of regrowth after 32 weeks, 59% of the women using ROGAINE rated their hair regrowth as moderate (19%) or minimal (40%). For comparison, 40% of the women using placebo (no active ingredient) rated their hair regrowth as moderate (7%) or minimal (33%). No regrowth was reported by 41% of the group using ROGAINE and 60% of the group using placebo

How soon can I expect results from using ROGAINE?
Studies show that the response time to ROGAINE may differ greatly from one person to another. A temporary increase in hair shedding may occur 2 to 6 weeks after starting treatment with ROGAINE as some hair follicles shift from the resting phase to the growth phase (as new hair growth begins, old hairs are released). An increase in shedding should not last more than a few weeks. If it does, your physician will need to rule out other causes. Successful hair regrowth can only be evaluated after continuous, twice-daily treatment for 4 months or longer.

How long do I need to use ROGAINE?
ROGAINE is a hair-loss treatment, not a cure. If you have new hair growth, you will need to continue using ROGAINE to keep or increase hair regrowth. If you do not begin to show new hair growth with ROGAINE after a reasonable period (at least 4 months), your doctor may advise you to discontinue using ROGAINE.

What happens if I stop using ROGAINE? Will I keep the new hair?
Probably not. People have reported that new hair growth was shed after they stopped using ROGAINE.

How much ROGAINE should I use?
You should apply a 1-mL dose of ROGAINE twice a day to your clean dry scalp, once in the morning and once at night before bedtime. Wash your hands after use if your fingers are used to apply ROGAINE. ROGAINE must remain on the scalp for at least 4 hours to ensure penetration into the scalp. Do not wash your hair for at least 4 hours after applying it. If you wash your hair before applying ROGAINE, be sure your scalp and hair are dry when you apply it. *Please refer to the Instructions for Use* in the package.

What if I miss a dose or forget to use ROGAINE?
Do not try to make up for missed applications of ROGAINE. You should restart your twice-daily doses and return to your usual schedule.

What are the most common side effects reported in clinical studies with ROGAINE?
Itching and other skin irritations of the treated scalp area were the most common side effects directly linked to ROGAINE in clinical studies. About 7 of every 100 people who used ROGAINE (7%) had these complaints.

Other side effects, including light-headedness, dizziness, and headaches, were reported both by people using ROGAINE and by those using the placebo solution with no minoxidil. You should ask your doctor to discuss side effects of ROGAINE with you.

People who are extra sensitive or allergic to minoxidil, propylene glycol, or ethanol should not use ROGAINE.

ROGAINE Topical Solution contains alcohol, which could cause burning or irritation of the eyes or sensitive skin areas. If ROGAINE accidentally gets into these areas, rinse the area with large amounts of cool tap water. Contact your doctor if the irritation does not go away.

What are some of the side effects people have reported?
ROGAINE was used by 3,857 patients (347 females) in placebo-controlled clinical trials. Except for dermatologic events (involving the skin), no individual reaction or reactions grouped by body systems appeared to be more common in the minoxidil-treated patients than in placebo-treated patients.

Dermatologic: irritant or allergic contact dermatitis – 7.36%; **Respiratory:** bronchitis, upper respiratory infection, sinusitis – 7.16%; **Gastrointestinal:** diarrhea, nausea, vomiting – 4.33%; **Neurologic:** headache, dizziness, faintness, light-headedness – 3.42%; **Musculoskeletal:** fractures, back pain, tendinitis, aches and pains – 2.59%; **Cardiovascular:** edema, chest pain, blood pressure increases/decreases, palpitations, pulse rate increases/decreases – 1.53%; **Allergic:** nonspecific allergic reactions, hives, allergic rhinitis, facial swelling, and sensitivity – 1.27%; **Metabolic-Nutritional:** edema, weight gain – 1.24%; **Special Senses:** conjunctivitis, ear infections, vertigo – 1.17%; **Genital Tract:** prostatitis, epididymitis, vaginitis, vulvitis, vaginal discharge/itching – 0.91%; **Urinary Tract:** urinary tract infections, renal calculi, urethritis – 0.93%; **Endocrine:** menstrual changes, breast symptoms – 0.47%; **Psychiatric:** anxiety, depression, fatigue – 0.36%; **Hematologic:** lymphadenopathy, thrombocytopenia, anemia – 0.31%.

ROGAINE use has been monitored for up to 5 years, and there has been no change in incidence or severity of reported adverse reactions. Additional adverse events have been reported since marketing ROGAINE and include eczema; hypertrichosis (excessive hair growth); local erythema (redness); pruritus (itching); dry skin/scalp flaking; sexual dysfunction, visual disturbances, including decreased visual acuity (clarity); increase in hair loss; and alopecia (hair loss).

Can ROGAINE Topical Solution cause unwanted hair growth?
Facial hair growth has been reported with the use of ROGAINE, particularly by women. The cause is unknown but may be related to continuous, unintentional exposure of the face to the medicine or to hair follicles on the face that are extremely sensitive to very low levels of medicine absorbed from the scalp. To minimize the chances of hair growth on the forehead or temples, wash your hands after applying ROGAINE and be careful not to transfer the medicine from your scalp to other parts of your body.

What are the possible side effects that could affect the heart and circulation when using ROGAINE?
Serious side effects have not been linked to ROGAINE in clinical studies. However, it is possible that they could occur if more than the recommended dose of ROGAINE were applied, because the active ingredient in ROGAINE is the same as that in minoxidil tablets. These effects appear to be dose related; that is, more effects are seen with higher doses.

Because very small amounts of minoxidil reach the blood when the recommended dose of ROGAINE is applied to the scalp, you should know about certain effects that may occur when the tablet form of minoxidil is used to treat high blood pressure. Minoxidil tablets lower blood pressure by relaxing the arteries, an effect called vasodilation. Vasodilation leads to fluid retention and faster heart rate. The following effects have occurred in some patients taking minoxidil tablets for high blood pressure:

Increased heart rate: some patients have reported that their resting heart rate increased by more than 20 beats per minute.

Salt and water retention: weight gain of more than 5 pounds in a short time or swelling of the face, hands, ankles, or stomach area.

Problems breathing: especially when lying down; a result of a buildup of body fluids or fluid around the heart.

Worsening or new attack of angina pectoris: brief, sudden chest pain.

When you apply ROGAINE to normal skin, very little minoxidil is absorbed. You probably will not have the possible effects caused by minoxidil tablets when you use ROGAINE. If, however, you experience any of the possible side effects listed above, stop using ROGAINE and consult your doctor. Any such effects would be most likely if ROGAINE was used on damaged or inflamed skin or in greater than recommended amounts.

In animal studies, minoxidil, in much larger amounts than would be absorbed from topical use (on skin) in people, has caused important heart-structure damage. This kind of damage has not been seen in humans given minoxidil tablets for high blood pressure at effective doses

What factors may increase the risk of serious side effects with ROGAINE?
People with a known or suspected heart condition or a tendency for heart failure would be at particular risk if increased heart rate or fluid retention were to occur. People with these kinds of heart problems should discuss the possible risks of treatment with their doctor if they choose to use ROGAINE.

ROGAINE should be used only on the balding scalp. Using ROGAINE on other parts of the body may increase minoxidil absorption, which may increase the chances of having side effects. You should not use ROGAINE if your scalp is irritated or sunburned, and you should not use it if you are using other skin treatments on your scalp.

Can people with high blood pressure use ROGAINE?
Most people with high blood pressure, including those taking high blood pressure medicine, can use ROGAINE but should be monitored closely by their doctor. Patients taking a blood pressure medicine called guanethidine should not use ROGAINE.

Should any precautions be followed?
People who use ROGAINE should see their doctor 1 month after starting ROGAINE and at least every 6 months thereafter. Stop using ROGAINE if any of the following occur: salt and water retention, problems breathing, faster heart rate, or chest pains.

Do not use ROGAINE if you are using other drugs applied to the scalp such as corticosteroids, retinoids, petrolatum, or agents that might increase absorption through the skin. ROGAINE is for use on the scalp only. Each 1 mL of solution contains 20 mg minoxidil, and accidental ingestion could cause unwanted effects.

Are there special precautions for women?
Pregnant women and nursing mothers should not use ROGAINE. Also, its effects on women during labor and delivery are not known. Efficacy in postmenopausal women has not been studied. Studies show the use of ROGAINE will not affect menstrual cycle length, amount of flow, or duration of the menstrual period. Discontinue using ROGAINE and consult your doctor as soon as possible if your menstrual period does not occur at the expected time.

Can ROGAINE be used by children?
No, the safety and effectiveness of ROGAINE has not been tested in people under age 18.

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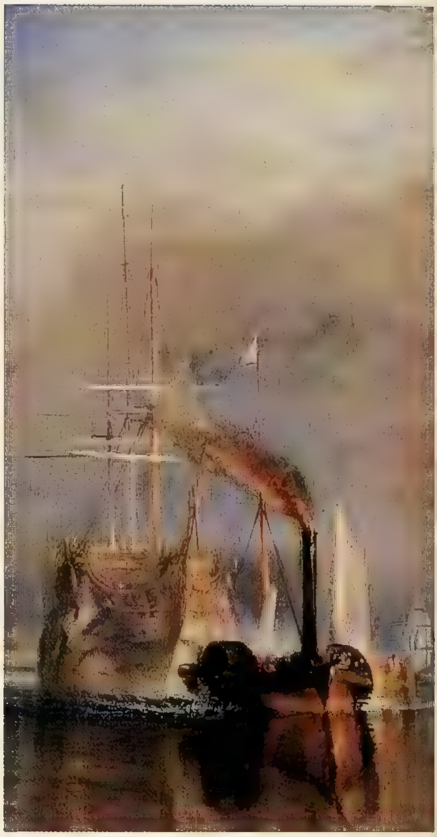
established a supremacy of British naval power that would endure for more than a century.

Nelson, "on board of the *Victory,*" engaged his flagship with the French *Redoutable*. The opposing ship fired at such close range that a French sniper, shooting from the mizzen-top of the *Redoutable,* easily picked off Nelson from a distance of only fifteen yards. Nelson died of this wound a few hours later, but with secure knowledge of his triumph.

Nelson's ship, and much of the battle, was saved by the second man-of-war on the line, the *Temeraire*. This vessel rescued the *Victory* by firing a port broadside into the *Redoutable* and disabling the French ship. (The mainmast of the *Redoutable* fell right across the *Temeraire*; the French ship then surrendered, and the victors boarded her and lashed the defeated vessel to the *Temeraire*'s port side.) Another French ship, the *Fougueux,* then attacked the *Temeraire,* but the British man-of-war fired her starboard broadside, to equally good effect, and secured her second prize, lashed this time to her starboard side. The *Temeraire,* now disabled herself, but with her two prizes lashed to her sides, had to be towed into port by a frigate.

Enter J. M. W. Turner (1775–1851), Britain's greatest nineteenth-century artist and the first subject of my second pairing. Early in his career, in 1806, Turner painted a conventionally heroic scene of the conflict: *The Battle of Trafalgar, As Seen from the Mizen Starboard Shrouds of the* Victory. We see Nelson, surrounded by his officers and dying on deck. The *Temeraire* stands in the background, firing away at the *Fougueux*.

Late in his career, in 1839, Turner returned to the ships of Trafalgar and depicted a very different scene, magnificent in philosophical and emotional meaning, and one of the world's most popular paintings ever since—*The Fighting* Temeraire, *Tugged to Her Last Berth to Be Broken Up, 1838.* (London's National Gallery of Art, appropriately located at the north end of Trafalgar Square, in the shadow of Nelson's pillar, is currently sponsoring a wonderful exhibit on this painting, including all major aspects of background and history. Such unitary exhibits are visual equivalents of essays, and I therefore love them dearly. We understand generalities best by focusing on the details of particulars.)


J.M.W. Turner's The Fighting *Temeraire* Tugged to Her Last Berth to Be Broken Up, 1838
The National Gallery

The large men-of-war, with their three major tiers of guns, were beautiful, terrible (in the old sense of inspiring terror), and awesome fighting machines. The *Temeraire,* constructed of oak, was built at Chatham and launched in 1798. The ship carried a crew of 750, far more than needed to sail the ship (with a gun deck 185 feet in length) but required to operate the 98 guns—for each gun required several men for the elaborate procedures of loading, aiming, firing, and controlling the kickback. But these "hearts of oak" (the favored patriotic name for the great men-of-war) fell victim to their own success. Their supremacy removed the threat of future war, while advancing technologies of steam and iron soon outpaced their wood and sails. They never fought again after the Napoleonic wars, and most were reduced to various workaday and unsentimental duties in or near port. The *Temeraire,* for example, was decommissioned in 1812 and then served as a floating prison and a victualing station.

Eventually, as timbers rotted and obsolescence advanced, these great vessels were stripped and sold to ship breakers to be dismantled for timber, plank by plank. John Beatson, a ship breaker at the yards of Rotherhithe, bought the *Temeraire* at auction for £5,530. Two steam tugs towed the hulk of the *Temeraire* for fifty-five miles from Sheerness to Rotherhithe in September 1838.

Turner's painting presents a wrenchingly dramatic view, quite inaccurate in an entirely studied way, of the *Temeraire*'s last, sad trip. The great man-of-war, ghostly white, still bears its three masts proudly, with light rigging in place and sails furled on the yards. The small steam tug, painted dark red to black, stands in front, smoke belching from its tall stack to obscure part of the *Temeraire*'s mast behind. One of Turner's most brilliant sunsets—with clear metaphorical meaning—occupies the right half of the painting. The most majestic and heart-stopping product of the old order sails passively to her death, towed by a relatively diminutive object of the new technology. John Ruskin wrote: "Of all pictures not visibly involving human pain, this is the most pathetic that ever was painted."

Turner clearly set his scene for romance and meaning, not for accuracy. Ships sold for timber were always demasted, so the *Temeraire* sailed to her doom as a hulk without masts, sails, or rigging of any sort—a most uninspiring, if truthful, image. Moreover, Rotherhithe lies due west of Sheerness, so the sun never could have set behind the *Temeraire*!

A simplistic and clearly false interpretation has often been presented for Turner's painting—one that, if true, would establish bitter hostility between art and science, thus subverting the aim of this essay: to argue that the two fields, while legitimately separate in some crucial ways, remain bound in ties of potentially friendly and reinforcing interaction. In this adversarial interpretation, recalling Blake's contrast of "dark Satanic mills" with "England's green and pleasant land," the little steam tug is a malicious enemy—a symbol of technology's power to debase and destroy all that previous art had created in nobility. In a famous, if misguided, assessment, William Makepeace Thackery (one of the thirty-eight in Gilbert's recipe for a heavy dragoon), wrote in 1839, when Turner first displayed his painting:

> The Fighting *Temeraire*—as grand a picture as ever figured on the walls of any academy, or came from the easel of any painter. The old *Temeraire* is dragged to her last home by a little, spiteful, diabolical steamer. . . . The little demon of a steamer is belching out a volume . . . of foul, lurid, red-hot malignant smoke, paddling furiously, and lashing up the water around it; while behind it . . . slow, sad and majestic, follows the brave old ship, with death, as it were, written on her.

This reading makes little sense because Turner, like so many artists of the nineteenth century, was captivated by new technologies and purposefully sought to include them in his paintings. (Alfred, Lord Tennyson, remains the best example of a poet who encountered science actively and positively, and sought to express the wonders, as well as the faults, of technology in his verse [see my essay in *Natural History*, November 1992]). In fact, Turner had a special fascination for steam, and he clearly delighted in mixing the dark smoke of the new technology with nature's lighter daytime colors.

In *Turner, The Fighting* Temeraire, her companion volume to the National Gallery's exhibit, Judy Egerton documents Turner's numerous and clearly loving paintings of steam vessels—starting

Please turn to page 62

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Death by Black Hole

by Neil de Grasse Tyson

Without a doubt, the most spectacular way to die in space is to fall into a black hole. Where else in the universe can you lose your life by being ripped apart atom by atom?

Black holes are regions where gravity is so great that the speed required to escape is greater than the speed of light. At exactly 299,792.458 kilometers per second in a vacuum, there is nothing faster in the universe. And if light cannot escape, then neither can you, which is why, of course, black holes are called black holes. All objects have escape speeds. Earth's is a mere eleven kilometers per second, so light escapes freely, as would anything else launched faster than eleven kilometers per second. Please tell all those people who like to proclaim "What goes up must come down!" that they are misinformed.

Albert Einstein's general theory of relativity, published in 1916, allows us to understand the bizarre structure of space and time in the vicinity of a black hole. But science fiction writers in search of fertile story lines have also probed the subject. For now, however, let's just explore in detail what black holes do to matter that comes a little too close to the "event horizon," the boundary between where light can and cannot escape—in other words, the region between what is in the universe and what is forever lost to the black hole.

If you were to fall freely feet-first into a black hole—do not try this at home—then the force of gravity would grow astronomically as you neared its center. Curiously, the black hole's enormous gravity itself is not what will kill you—you are always weightless when in free fall. Instead, you would be pulled apart as a result of the difference between the force of gravity at your feet and at your head. This differential, known officially as the tidal force, tries to accelerate your feet toward the black hole faster than your head. If humans were made of rubber, then you would just stretch. But we are made of bones and muscles and organs. Your body would stay whole only until the tidal force exceeded the strength of the chemical bonds of your flesh. The moment this happened, your body would systematically snap into countless tiny segments.

But there is more bad news.

All parts of your body would be moving toward the same spot—the black hole's center. So while you would be ripped apart head-to-toe, you would also be extruded through space like toothpaste being squeezed out of its tube. The result? Your once-whole body would quickly be squished into a string of falling atoms.

As a black hole eats, its diameter grows in direct proportion to its mass. If, for example, it pulls in enough matter to triple its mass, it will become three times as wide. Because their dimensions vary according to how much matter they consume, black holes in the universe come in almost any size. But not all of them will kill you in the manner described above. Those that will do the most severe damage are the smaller ones, with relatively low mass. Why? Because the strength of the tidal force is heavily dependent both on your size and your distance from the center of the object pulling on you. Since smaller black holes allow you to get much closer to their centers before you cross their event horizons, the change in gravity can be devastating to fallers-in.

One common variety of black hole—the type that high-mass stars evolve into—contains several times the mass of the sun compacted deep within an event horizon that is only about a dozen miles across. In a fall toward such a black hole, you would begin to break apart within about 100 miles of the center. Other common black holes are up to billions of times the mass of the sun and are contained within event horizons that are nearly as wide as the entire solar system. One might find this type lurking in the center of some galaxies. While gravity in such a huge black hole is strong, the difference in gravity from your head to your toes near their event horizons is relatively small. In such cases, the tidal force would be so weak that you might even fall through the event horizon in one piece—you just wouldn't ever be able to come back out and tell anybody about your trip.

As far as I know, nobody has ever been eaten by a black hole, but there is compelling evidence to suggest that black holes routinely dine upon entire stars and large gas clouds that come too close. A gas cloud hardly ever falls straight into a black hole. Unlike you in your feet-first fall (where you aimed straight for the black hole's center), a gas cloud is typically drawn into an orbit before it spirals to its destruction. The parts of the cloud that are closest to the black hole will orbit faster than the parts that are farther away. This differential rotation can have extraordinary astrophysical consequences. The cloud heats up from internal friction to hundreds of thousands of degrees—much hotter than the surface of any normal star. The gas glows blue-hot as it becomes a copious source of ultraviolet and X-ray energy. What began as an isolated, invisible black hole (minding its own business) has now become an invisible black hole whose presence can be deduced because it is encircled by a gaseous speedway ablaze with high-energy radiation.

Since stars are 100-percent certified balls of gas, they are not immune from this same fate. A star will first be stretched by a black hole's tidal forces but will eventually shear into a friction-heated disk of highly luminous gas. If two stars are in mutual orbit and one becomes a black hole, then the black hole does not get to eat until very late in the companion star's life—when it swells to become a red giant. If the red giant grows large enough, then it will be flayed by the black hole as layer after layer gets peeled and eaten.

Whenever a theoretical astrophysicist needs to find a potent energy source occupying a tiny space to explain a mysterious phenomenon, then well-fed black holes become prime suspects. The strange, distant quasars are good examples. They are hundreds or thousands of times more luminous than the entire Milky Way galaxy, yet their energy emanates primarily from a volume that is not much larger than our solar system. Without invoking a supermassive black hole as the central engine, our ability to explain quasars is severely compromised.

There is now excellent evidence to show that supermassive black holes really do exist in the cores of galaxies. In some cases, suspiciously high luminosity in a suspiciously small space is enough to raise an eyebrow. The actual luminosity depends on how many stars and gas clouds are available for the black holes to shear apart. Other galaxies may host a supermassive black hole that has already eaten most of the matter in its vicinity. In such a case, the black hole will not reveal itself by the luminosity of the food on its plate. But stars orbiting close by—but not too close to be consumed—will be moving at suspiciously high speeds.

Individual stars cannot yet be observed close to the centers of galaxies. But in a delicate and challenging procedure, a characteristic speed can be inferred from analysis of the blended light of hundreds (or thousands) of stars. This speed, when combined with the stars' average distance from the center of the galaxy, is a direct measure of the total mass contained within their orbits. Armed with these data, we need no more than the back of an envelope to compute whether the attracting central mass is, indeed, concentrated enough to be a black hole candidate. One of the largest black holes known, containing the equivalent of one billion solar masses, was recently inferred for the center of the galaxy NGC3115 by John Kormendy, of the University of Hawaii, and Doug Richstone, of the University of Michigan. NGC3115 is a gas-poor, edge-on spiral galaxy that is about 15 million light-years away in the direction of constellation Sextans. No need to be jealous: mounting evidence shows that the center of our own Milky Way galaxy may harbor a 2-million-solar-mass central black hole of its own.

Reflecting on the beauty, mystery, and danger of black holes prompts me to agree with J. B. S. Haldane when, in 1927, he penned, "The universe is not only queerer than we suppose, but queerer than we can suppose."

Neil de Grasse Tyson is an astrophysicist with a joint appointment at the Hayden Planetarium and Princeton University.

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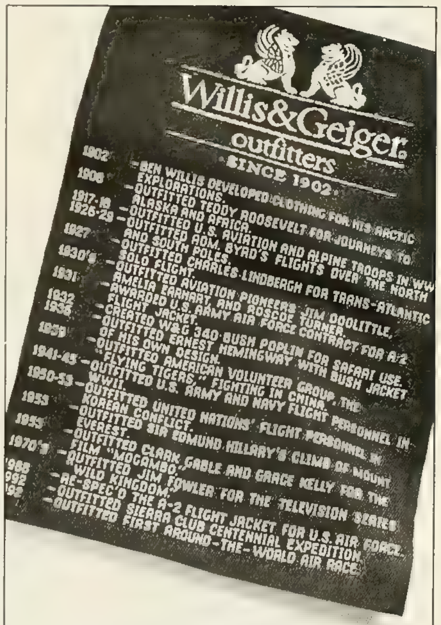

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Crichton's Jurassic Replay; Bakker's *Utahraptor Romance*

by James Gorman

THE LOST WORLD, by Michael Crichton. *Alfred A. Knopf, Inc., $25.00; 416 pp.*
RAPTOR RED, by Robert T. Bakker. *Bantam Books, $21.95; 246 pp.*

Michael Crichton offers several epigraphs at the beginning of *The Lost World,* the sequel to *Jurassic Park.* One of them is from Ian Malcolm, the fatuous and fictional chaos theorist from the first book. "Sequelae are inherently unpredictable," says Malcolm. Not this one.

The Lost World—the title echoes that of an Arthur Conan Doyle book about a South American jungle mesa where the dinosaurs somehow survived—is a formulaic, premovie thriller providing the basis for a film as alike as possible to *Jurassic Park* without being a total remake.

Crichton, of course, knows the drill—quick scene changes, main plot and subplot, good guys and bad guys, and a lot of scientific detail. To be fair, the plot of *The Lost World* is not exactly what we might expect after having read *Jurassic Park.* In that book, hints were dropped of dinosaurs escaping from the original, ill-fated island theme park and reaching the mainland of Central America. Similar hints are dropped at the beginning of this book too. But although dinosaur lovers across the heartland have been yearning for slavering raptors to migrate north and chase surfer dudes through the kitchens of La Jolla, it doesn't happen. My bet is that Crichton is saving up such scenes for a third book.

Otherwise, it's *déjà vu* all over again. There are more nouveau dinosaurs trying to eat a different pair of kids. There's a beautiful, savvy female scientist and a self-important male scientist (in addition to Malcolm), whose intellectual greed and emotional immaturity get everyone in trouble—Faust as nerd. There are really bad bad guys who want to steal the dinosaurs. And there is no end of fancy gadgets for tracking and fighting off dinosaurs.

Crichton has done his homework. His dinosaurs are all plausible. His plot twists could happen. I know a bit about dinosaurs, so I know that Crichton takes care to be in the ballpark with his biology. There's no evidence that *Compsognathus* had venom, but there's no evidence that it didn't. But I confess to suspicion about his version of chaos theory. When it comes to chaos, I'm like most readers. I have no expertise. So I have to scratch my head when Crichton's Ian Malcolm keeps saying things like, "At the edge of chaos, unexpected outcomes occur. The risk to survival is severe." Does that mean, "When things go haywire, watch your back"? Is that chaos theory? I hope not. Either I am an unusually obtuse reader, or the sum of chaos theory, as Crichton presents it, is that the more complicated things get, the harder it is to know how they'll turn out in the end. Suffice it to say *The Lost World* is not that complicated.

Not only do dinosaur addicts have *The Lost World* and its eventual movie version to look forward to, they also have *Raptor Red,* by Robert T. Bakker, an attempt to write a novel from a dinosaur's point of view. Now, that's unpredictable. In his book, Bakker describes himself as an unofficial consultant for the film *Jurassic Park,* and *Raptor Red* is a kind of unofficial "prequel," a gloss on the movie that charts the life of a female *Utahraptor* in the early Cretaceous. Fossils of this species were first found while the movie's raptors were being created, and Bakker sets out to tell the creature's "real" story.

There are two familiar ways to tell animal tales. One is the Rudyard Kipling mode, in which the animals are characters every bit as human as the people in Dickens. Rikki Tikki Tavi, Kipling's fearless little mongoose, is probably my favorite character in all of literature. Another method is to try in some way to penetrate the consciousness of animals. This is probably done most often with dogs, which we tend to consider half-human anyway. Jack London takes this approach in *The Call of the Wild,* for example, and so does Bakker. He tries to write from inside the heads of dinosaurs, pterodactyls, mammals, and even turtles.

This may sound like a tough job, but although Bakker has his critics in paleontology, nobody has ever accused him of lack of imagination. The basic story is girl loses boy, meets boy, loses boy, gets boy—the girl and boy in question being *Utahraptor* dinosaurs. In terms of personality, Bakker's raptor comes off like a bloody-minded Jane Austen character—bound by family ties, thoroughly responsible, yet longing for independence and love. Of course Austen's way of describing this differs considerably from Bakker's: "Her subconscious computer has a hard and fast rule: Take care of your own chicks first; each one is one half of yourself. Take care of your sister's chicks next. Don't waste time on any other blood relative."

No penurious matron of a country house struggling with genteel poverty could have put it more clearly. Sometimes, however, Bakker waxes downright sentimental. Of another *Utahraptor,* not the heroine, he writes with feeling, "She's very sad. All day males have rejected her. All day her unusual size has caused anxiety in potential mates. She's the victim of discrimination built into the courtship instinct, the inbred distrust of anyone who is too different from the norm. With her body held low, the unhappy giant walks away, not looking back."

Raptor Red is not all about unrequited love. This is not just a dinosaur romance novel. There are plenty of fights, and there's also physiology. "The metabolic furnace within her body is up to the thermal challenge. Waves of shivering spread through her muscles, and her heat production goes up by another factor of four, keeping all her vital organs at an optimum temperature of 100 degrees Fahrenheit."

And there's the philosophical pterodactyl, which appears late in the book like a character from legend—"the great white dactyl." Bakker writes, "The dactyl climbs to five hundred feet to survey the scene. . . . He likes intervening in the lives of predators—it amuses him. He's spent all his waking hours amusing himself, ever since that day in the spring when he decided he would not take a mate."

Is this what the mind of a pterodactyl was like? Did dinosaurs really think and feel this way? Who knows? Not Robert Bakker, certainly, despite the suggestion that these monologues are somehow built on scientific fact. We have a hard enough time figuring out what human consciousness is, let alone what a living, breathing mammal experiences, let alone a dinosaur.

Nonetheless, Bakker's book, for all its clumsiness and naiveté, is still more intriguing than Crichton's. It is idiosyncratic and thoroughly heartfelt. It has the charm of a beginner's handmade pot, the appeal of folk art. If you have to read someone's fantasies of dinosaurs, it might as well be Bakker's. Besides, this book, unlike Crichton's sequel, is unpredictable.

James Gorman is the author, with paleontologist John R. Horner, of Digging Dinosaurs *and* Maia: A Dinosaur Grows Up. *He is an editor at the* New York Times.

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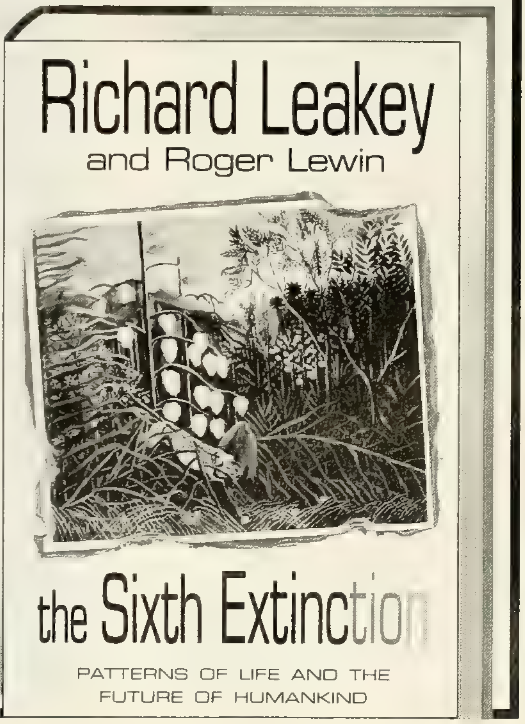
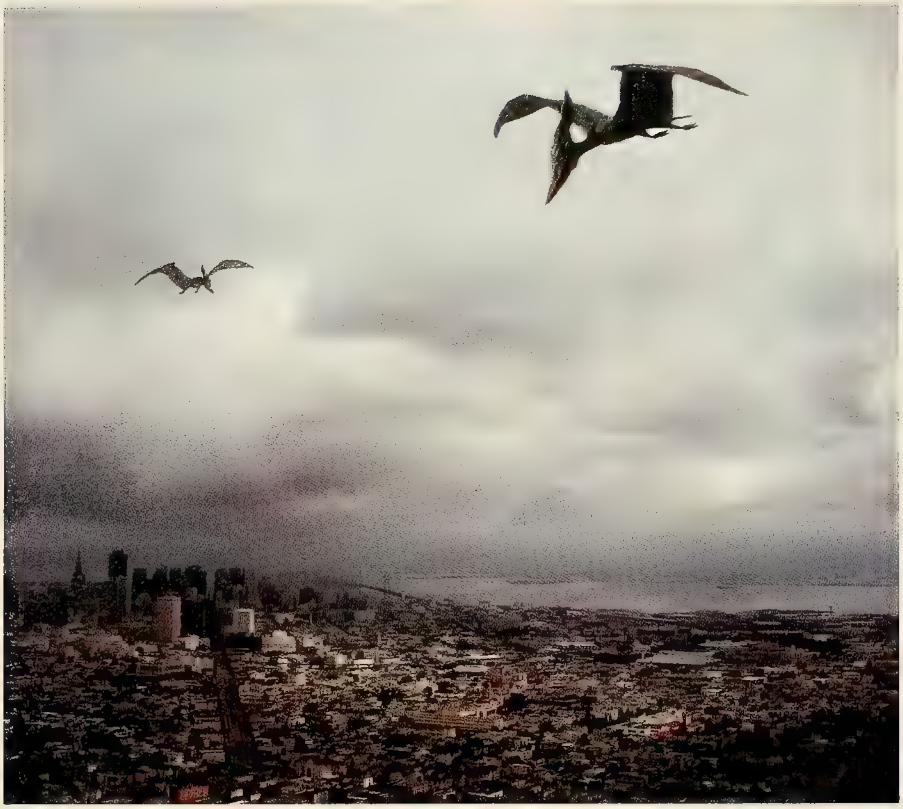




Pteranodon over San Francisco

Sightings

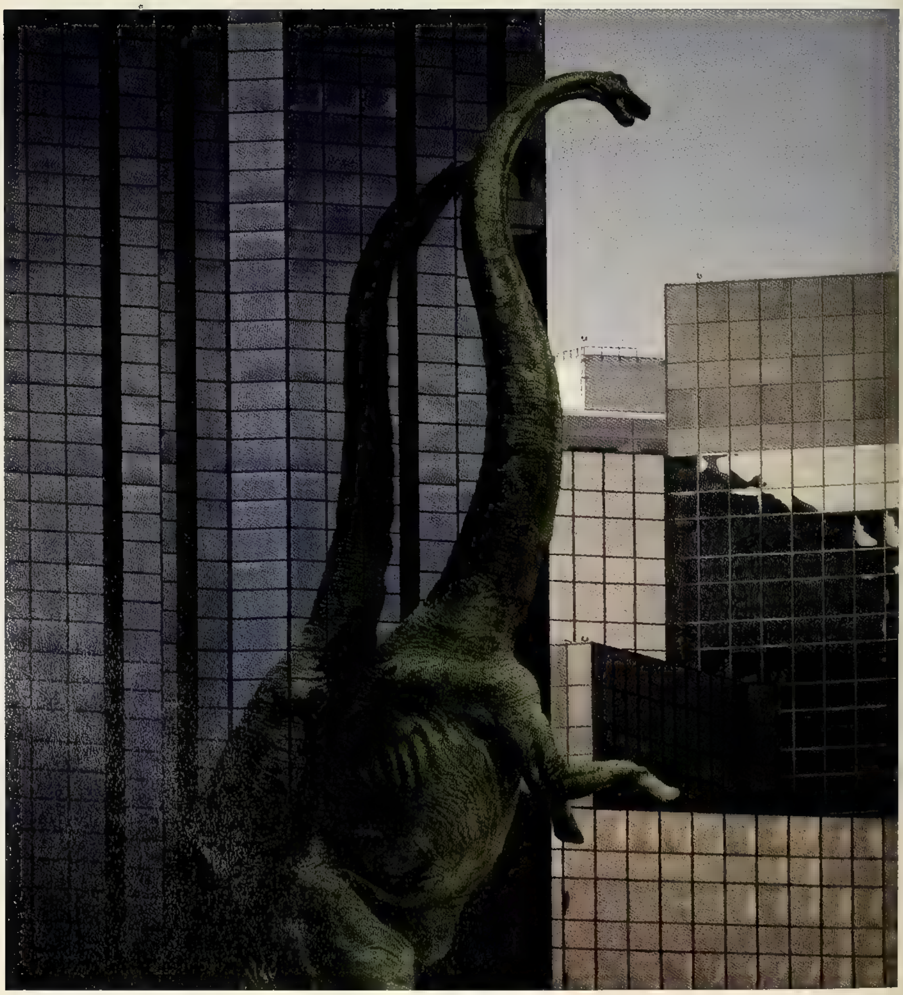
Digital Creatures in an Analog Land

Photo images and text by
Teruhisa Tajima

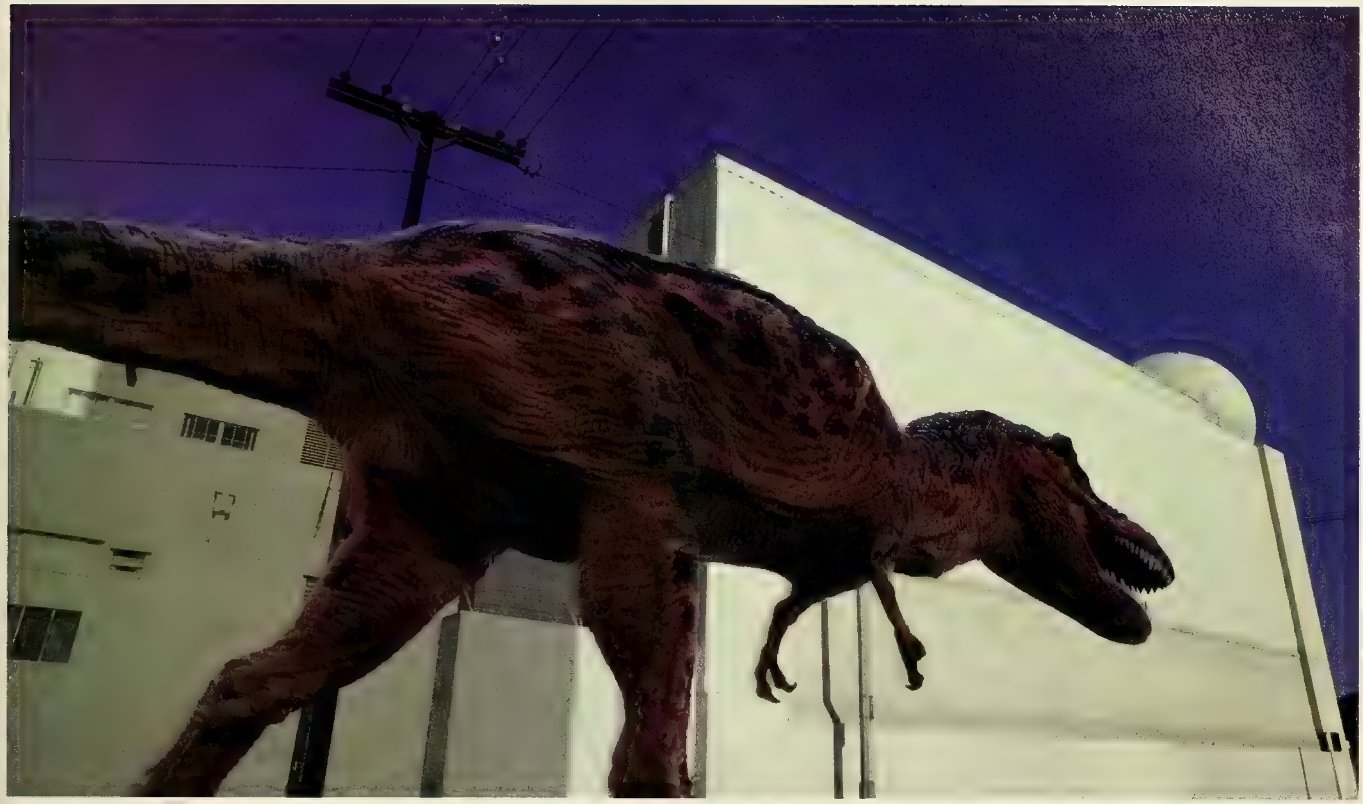
Teruhisa Tajima was born in Japan in 1949 and is a graduate of the Graphic Design Department of Tama Art University. He began experimenting with digital design and photography in 1988.

Excerpted from *Dinopix* by Teruhisa Tajima, published by Chronicle Books, 1995

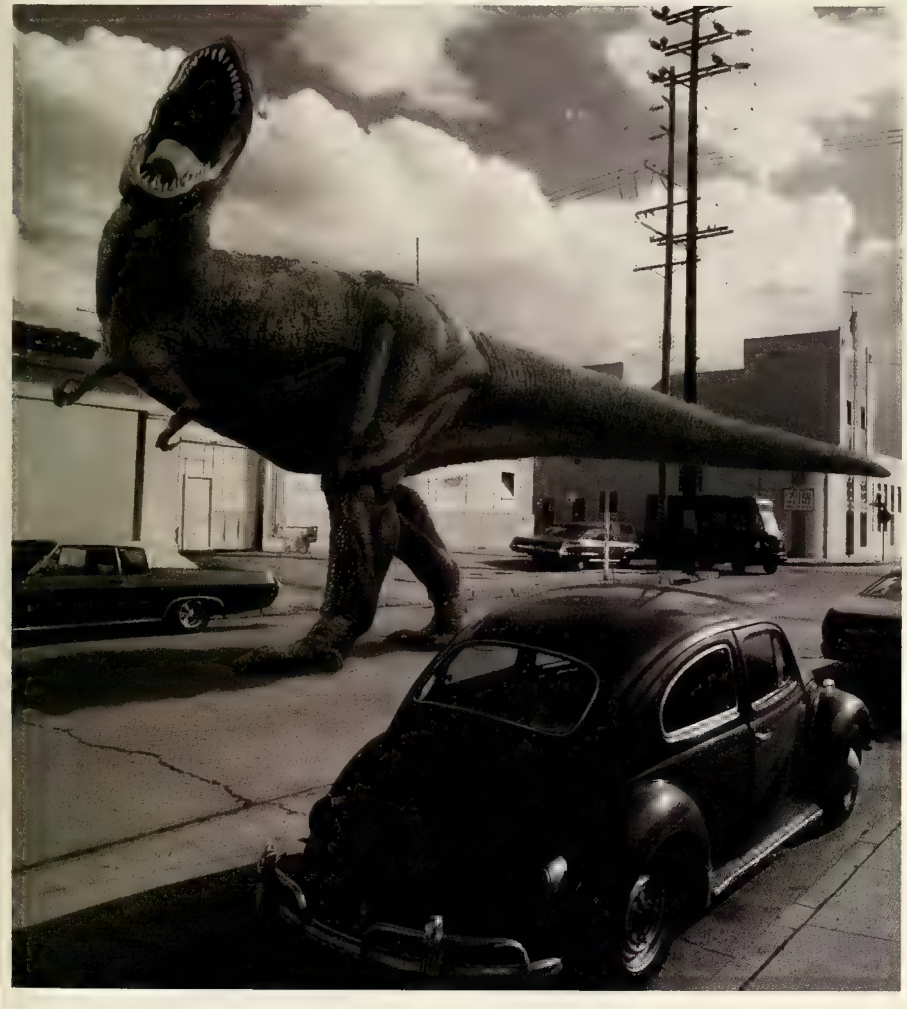
In the fall of 1992, I visited Arches National Park in Utah. There, far off in the orange-colored morning mist, on the other side of the plain, I saw figures of nocturnal raptors hurrying home; I imagined long-necked brachiosaurs casting shadows across the rock surfaces deeply reddening in the morning sun. Long ago I wanted to see these creatures with my own eyes, just as any child wishes to do. I wondered if they might be around somewhere, if it would be possible to see one, and what on earth they really looked like.



Barosaurus in Edmonton



Tyrannosaurus in Hollywood I



I realized that one way to revive them existed in the cathode-ray tube in front of me. It seemed too simple, but if the desired fantasy could become reality through the digital circuitry so popular today, why not try it. I resolved to try to reproduce creatures that would appear to be alive through the application of natural light to dinosaur replicas created in the analog world, adding moistness to their skin, tension to their muscles, so that they would become the creatures of my youthful imaginings. To be honest, I was looking forward to seeing these images more than anyone else.

Tyrannosaurus in Hollywood II

Hope for the Botanically Challenged

by Steven Austad

The Private Life of Plants: A Natural History of Plant Behaviour, by David Attenborough. *Princeton University Press, $26.95; 320 pp., illus.* This book accompanies a six-part television series, airing on TBS Superstation from October 9 to 14.

I first realized that I was among the botanically challenged one raw spring day while crossing Harvard Yard with a plant-enthusiast friend of mine. The wind was blasting the ancient elm trees in the Yard, making seeds rain on the paved walkways below. There, scurrying students heedlessly ground the seeds underfoot. "My God," said my friend in something between real and mock horror, "look at all the road kills."

To make that observation requires a certain imagination—an imagination that I unfortunately lack. But it does point out how a visceral appreciation of plants requires an awareness of fulfilled or squandered possibilities rather than the mere observation of intrinsically dramatic events. Appreciation of plants also presupposes an ability to come unstuck in time, like Billy Pilgrim in Kurt Vonnegut's novel *Slaughterhouse Five*. After all, plants do little that we can actually observe in everyday human time, except perhaps attract animals that are more immediately rewarding to watch.

Not that plants don't perform all the same biological necessities—voyaging, mating, sacrificing, fighting, aging, manipulating, and deceiving—in as interesting a fashion as animals. But they operate on a different time scale, one more suited to, say, weathering house paint or people who drive ten miles per hour below the speed limit.

In principle, if we get the perverse thrill that most of us do from seeing a lion eviscerate a wildebeest, then we might also find the spectacle of a fungus eviscerating an oak thrilling—if we had a few years to spend watching it happen. Alternatively, we can view David Attenborough's new television series, *The Private Life of Plants*, and let the camera speed up the evisceration to a rate that is indeed thrilling.

The series doesn't only cover plants. It also covers fungi and algae and might more properly be titled *The Private Life of Things That Aren't Animals and That Most People Think Are Boring*. But the series is anything but boring and represents what I think is Attenborough's best work so far. The medium of film, with all its tricks of time lapse, slow motion, stop motion, and animation, is ideal for dramatizing the superficially mundane. And Attenborough has used all these tricks to excellent effect. Besides the expected, but spectacular, time-lapse shots of sprouting leaves, blooming flowers, and ripening fruit, we also see leaves dance and dodge as they try to track spots of sunlight fluttering across the forest floor; vine tendrils lassoing twigs as neatly as any cowboy; and toadflax reaching high to tamp its seeds inside castle wall crevices as precisely as a persnickety gardener.

In addition to these cinematic tricks, there is the usual incredible photography—the perspectives so difficult to get and so exquisite to perceive that any normal nature documentary would be built around one such sequence. Yet this Attenborough series packs in many such shots: ants slipping into a pitcher plant's throat, taken from beneath the liquid inside the pitcher plant; the fate of the seeds inside the chambers of an ant colony; or close-ups of a hummingbird so near and clear that we can almost count the individual pollen grains on its beak.

Attenborough's gift should not be misunderstood as merely a talent for recognizing and arranging superior cinematography. He also has a knack of identifying especially intriguing phenomena and knowing how to dramatize them. The usual suspects are here, of course—the giant sequoia for its immense size, the bristlecone pine for its great age. But more typically, he dramatizes something less well appreciated, such as the remarkable ability of trees to draw groundwater up into their canopies. To do this, he mounts a fire truck's ladder, rides it up into the canopy, turns on the fire hose, and over the roar of the truck's pump, explains how a tree performs the same task—silently.

The reason Attenborough's cinematic narratives are so compelling is that he himself is astounded by what he's working with. He conveys this admiration superbly in his book, which is drawn from the series. The opening lines set the tone: "Plants can see. They can count and communicate with one another. They are able to react to the slightest touch and to estimate time with extraordinary precision." He backs up these extravagant claims almost immediately. By the end of the series, had he said that plants first discovered symbolic logic, I might have believed him.

The book's six chapters parallel the organization of the six one-hour shows, expanding on most topics, adding others, and including different examples and additional details. One thing the book cannot replicate is Attenborough's wonderful camera persona—the unconscious and endearing nerdiness possessed by the best teachers. He sprawls on the forest floor to look at the undersides of leaves, squashes his face into the ground to point out a small flower, gives a stage sneeze to dramatize allergies to pollen, enthusiastically scoops up fresh elephant dung to show the acacia seeds embedded in it. He even manages not to look too nauseated while eating a freshly hacked-open durian fruit, whose infamous aroma he has just described as like "an

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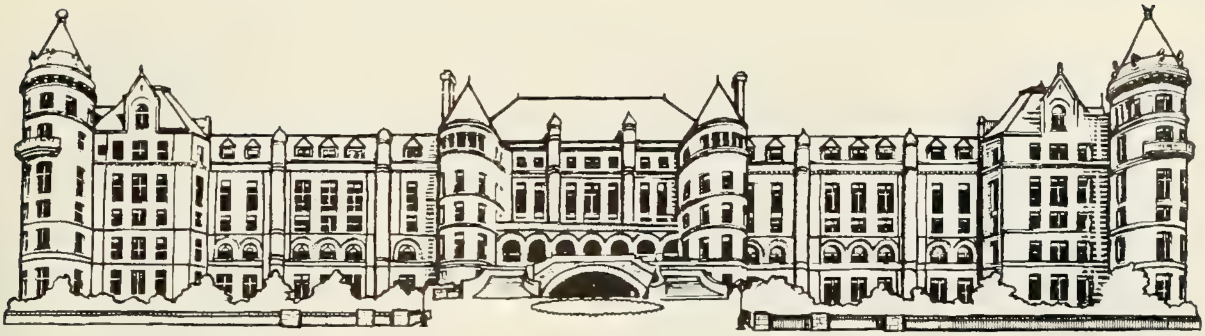

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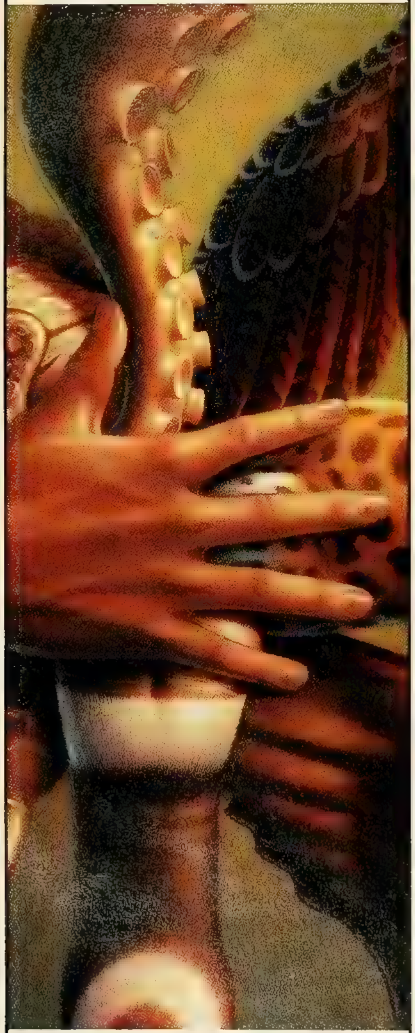

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open sewer with just a dash of coal gas."

I'm also particularly fond of his staccato, emphatic, slightly breathless delivery, often while bobbing his head like a dashboard puppy. No simple script reader, he puts himself smack in the middle of the story at all costs: brushing his hand against nettles or yelping while being bitten by ants or choking on smoke while trying to talk in front of an African bush fire. He climbs trees, he scuba dives, he strides through chest-deep water. From time to time, his hands and face have dried blood on them. You have to love this sort of involvement.

Having myself worked on the set of a number of low-grade, baldly bogus nature documentaries (which, for example, would try to pass off the southern California chaparral for African savanna, or use a midget in a chimp suit for a chimpanzee), I couldn't help but wonder how many of the dramatic details that we see and hear in this series are products of theatrical license. Attenborough gets his facts right, to be sure. That is among the things that separate his productions from other nature documentaries and make his work so popular with professional biologists. But what about the sounds? The caterpillars that crunch as they eat leaves; the crisp, crinkling sound of opening flowers; the helicopterlike flapping of sycamore seeds? These are time-lapse sequences in which such sounds couldn't have been simultaneously recorded. So was someone, somewhere, crinkling cellophane into a microphone to get this effect?

I also wonder about Attenborough's breathlessness. I remember hearing the possibly apocryphal story that Dustin Hoffman, while working on the movie *Marathon Man*, would run himself to exhaustion so that he could look properly spent and bedraggled during the scenes in which he was being chased by the movie's villain, Laurence Olivier. Hoffman supposedly asked Olivier how *he* prepared for such scenes, and Olivier supposedly responded "I *act*." I wonder if Attenborough acts or if he actually climbs the tree just before emerging, hard hat slightly askew, from the top of its hollow trunk, speaking breathlessly? Either way, these effects are pleasing, and this sort of speculation can interest me on quite another level.

David Attenborough examines Nepenthes rajah*—the largest pitcher plant—in Sabah, Malaysia.*

M. Salisbury

For those who still need to be convinced that this series will be exciting or who think they have no interest in plants, be assured that animals are not slighted. Rhinos, elephants, and birds munch fruit, crunch seeds, and defecate close-up and in slow motion. Insects, birds, and bats eat plants or their pollen. Other animals are eaten by plants. Even jellyfish, with internal photosynthetic symbionts, chase the sun back and forth across a pond. In short, there is something in both the film and the book for anyone with an interest in nature that extends beyond their doorway.

Biologists generally have a love-hate relationship with science popularizers. They love the attention but hate the factual errors, the oversimplifications, and the often-sentimentalized product. I'm particularly prone to this and usually avoid reading or watching any journalistic account of my own work for fear I will be terminally irritated. But if I am any example, biologists will have a much simpler relationship with David Attenborough than with the media as a whole. It consists of pure envy with just a dash of admiration.

Former lion trainer Steven Austad is an associate professor in the Department of Biological Sciences at the University of Idaho.

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American Pie

A pioneer woman's pride in her kitchen was expressed through her pies

by Roger L. Welsch

Which food is the soul of America? The answer is as close to our hearts (and stomachs) as Mom, Flag, and . . . Apple Pie.

Sure, when people of other nations think of American food, the hamburger comes to mind, and maybe even Americans think of the hamburger as American fare, given its evolution during the past century or so. But the "hamburg-er" in its origin is the sausage peculiar to Hamburg, Germany (while the wiener is the sausage peculiar to Vienna and the frankfurter is the sausage peculiar to Frankfurt, which pretty well eliminates the hot dog as the soul of American cuisine, Fourth of July and baseball notwithstanding).

Maybe the hamburger is the food best suited to the American life style, easily pitched into a still-moving car from the drive-in service window of a McDonald's, gulped while the "diner" ricochets from place to place, complemented by French fries. In what is arguably the most common of American meals, the French and the Germans come together in American stomachs a million times a day, a gastric reenactment of two world wars.

Steak is the most popular last meal for those about to leave death row the hard way, and it's mine too, although my doctor tells me I'm signing my own death warrant by eating it. (Don't bother writing me from the ranch to tell me how healthy beef is; your figures are based on moderate portions, and moderation has never been my forte, especially when it comes to good beef.)

But nothing as easily as pie stands for everything decent, good, honest, homey, and American. Some people don't eat pork. Some don't eat any meat. Some people don't ingest caffeine or alcohol. Is there anyone who, as a statement of ethics or conscience, doesn't eat pie?

It's been that way a long time. On the Great Plains, a pioneer woman's pride in her kitchen was expressed through her pies. Whatever she may have served at her family's table, when it came to public display, her pie was the emblem of her mastery. An elderly woman once told me a story about making pies for a church dinner, a story she clearly thought was funny, but which has haunted me as a troubling, even painful narrative ever since.

She said that when she had readied a couple of pies for baking—pies that would be seen and tacitly judged at the church that evening by all the other ladies of the community—she took the leftover crust dough and (as is still the custom in my mother's kitchen) rolled out the scraps, ladled in a teaspoon or two of jam, folded the dough over, sprinkled it with sugar or cinnamon, and then baked the remnants along with the pies. These "thin pies" she then packed up as a treat to be enjoyed the next day by the men working in the fields.

Well, her husband thought he would pull a practical joke and at the same time insure that he and the hands helping him in the harvest would enjoy the good pies. He took the church-bound pies out of the covered bushel basket they were in and hid them in the still-warm oven. And in their place he put the thin pies. That evening the wife turned her basket over to the woman in charge of the church dinner, and when the meal was on the table, our proud cook saw not her finest workmanship there but those wretched, ragged thin pies.

How does someone deal with that kind of humiliation? The next day the woman of the house said not a single word to her menfolk as she fed them breakfast and prepared to send them to the fields. Baskets of food, burlap-covered water jugs, and a box with the ill-gotten pies were placed in the field wagon, and the men

went to work, feeling a little chagrined, perhaps, maybe even a little uneasy about their prank.

When lunchtime came, the sandwiches tasted as good as ever, the water and lemonade were refreshingly cold, and the pies looked and smelled glorious. But then the men cut into the pies and found that the Little Lady had gotten up early in the morning and gone to the trouble of fixing them a little something special: a couple of feather pies, giving new meaning to the old rhyme about "four-and-twenty blackbirds, baked in a pie."

The woman said the men came home from the fields chastened, and although she never again took pies to church without checking her basket, the prank was never repeated. There are a lot of punishments, but to be tempted with pie and then denied left a lasting impression.

Any pie is a temptation, but one in particular has become the American icon, with connotations of the patriotic and divine—apple pie. This is somewhat ironic, since much of the apple's place in our folklore suggests an unsavory quality—the snake's apple in the Garden, the apple that was the instrument of William Tell's ordeal, the one apple in its absolute rottenness able to taint the barrel. And yet the apple retains by and large a wholesome image—"an apple a day," "in apple-pie order," "the apple of my eye." As nineteenth-century poet and journalist Eugene Field wrote,

> No matter what conditions
> Dyspeptic come to feaze
> The best of all physicians
> Is apple pie and cheese!

The pioneers who came to the Great Plains in the last century found a landscape with few trees and therefore little fruit. Wild plums, sand cherries, and rhubarb were pressed into service as pie filling. Dried apples were available but reportedly were "tough, leathery, dirty brown in color, and nearly always fly-specked." One Nebraska settler's ditty expressed a general opinion:

> Spit in my ear and tell me lies,
> But give me no more dried apple pies.

The solution was "mock apple pie," a standard on the Plains a hundred years ago. This version is from the Dakota City, Nebraska, *Mail* of May 22, 1874:

> Take six soda crackers. Break them in a dish and pour over them two cups of cold water. Let them stand until they can be reduced to a pulp. One-and-one-half cups of sugar, two teaspoons of tartaric acid, and flavor to taste with lemon. This is sufficient for two pies.

(If you hope to try this recipe, note that "soda crackers" of the time were brick-hard and the size of a slice of bread.)

Some friends and I once stopped in a small, remote cafe in Arthur, Nebraska, for lunch. The meal was good. I suppose we shouldn't have been surprised, but when you eat on the road in America, you learn not to expect too much. When it came time to order dessert, we noted that the menu said "homemade pie." But we were skeptical. They say never to eat in a cafe named "Mom's," and we were thinking the same sort of thing about this "homemade" pie. The commercial world knows that the word "homemade" sells pie, and it sells bad pie about as successfully as good pie, the idea being, I suppose, that like sex, there is only great pie and fairly great pie. This time we were lucky—the pie was superb and the ice cream was homemade too. We thought we'd died and gone to heaven.

But *real* homemade pie remains just that. It has to have holes cut in the top crust with a butter knife or poked with a fork. And the top and bottom crusts must be lovingly joined by the pinches of a mother's finger and thumb.

Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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Nourishing pies of Montana

Photographs by David Burnett; Contact Press Images

Hammerhead City

Magnetic undersea peaks may be the hub of the shark's social and navigational worlds

Text by A. Peter Klimley
Photographs by Paul Humann

About fifteen miles east of the Baja peninsula, submerged in the Gulf of California, is a craggy underwater mountain known as Espiritu Santo. Like many basaltic volcanic peaks, it is a mecca for sea creatures. Among the many species of fish at Espiritu Santo are green jack and pompano, whose schools number in the thousands. Regular visitors also include snappers, sailfish, marlin, manta rays, reef sharks, and an occasional whale shark. But what draws me there year after year are the spectacular schools of scalloped hammerhead sharks—from fifty to two hundred of them, many more than seven feet long—that swim around the seamount all day.

Many of the smaller fish at the seamount are plankton feeders, attracted by the local richness of algae and invertebrate larvae. But hammerhead sharks do not gather there to dine on smaller fish. Why, then, do hammerheads school at these underwater mountains? Indeed, why would such big sharks with no natural enemies school at all? After fifteen years of observation and experiments, and hundreds of hours of swimming among hammerheads, I've begun to understand why seamounts are the center of their world.

I had first read about these sharks fifteen years ago, when I was a graduate student at the Scripps Institution of Oceanography; a professor showed me some unpublished field notes by Earl Herald, former director of the Steinhart Aquarium. Herald had seen an immense school of these enigmatic predators at an undersea pinnacle off a remote island called Los Animas, in the Gulf of California. In my early attempts to find a hammerhead school, I dumped large amounts of chum (fish meat and oils) into the water, hoping to draw them to my boat. I also tried playing low-frequency, pulsed sounds underwater, similar to those emitted by small fish, but hammerheads never showed up.

Why would large predators with no natural enemies form schools of 200 or more?

Scalloped hammerhead sharks school in the Galápagos, near a volcanic island.

A nocturnal feeder, a hammerhead takes an afternoon swim through a school of creolefish without preying on them.

It took more than a year of searching to find my first school of hammerheads, the one at Espiritu Santo. My colleague Don Nelson, of California State University at Long Beach, recreational diver Ted Rulison, and I spotted some swimming at the surface near a rocky island. We quickly donned scuba gear and scrambled into the water. But when we pursued them, the sharks dispersed.

The next day we returned to the spot. Swimming about seventy-five feet from the boat, Ted suddenly shouted, "They're here, and hundreds of them, too." Realizing that we may have previously frightened the hammerheads with our noisy scuba bubbles, we entered the water without air tanks. This time we could make out the shapes of fifty or more sharks swimming just below us, circling above the peak of an underwater seamount. We held our breath and swam downward. Soon we were within the school, with large sharks above, to the sides, and below us. Exhilarated at finding them, we were also somewhat apprehensive; no one knew whether the hammerheads would attack. Instead, they seemed to accept our presence.

After our initial contact, we made plans for a more formal study. I spent many days diving without an air tank, closely observing individual hammerheads. Over and over I would dive down to about seventy feet and remain submerged for a minute and a half while taking photographs or making videotapes. We also wanted to know where the sharks went when they weren't at the seamount. To find out, we implanted small transmitters in individuals so we could track them, both during their days at the seamount and at night when they moved into the surrounding deep waters. Using a pole spear, I swam up to targeted animals and implanted the devices with a quick jab. On a computer screen aboard our boat we could then monitor a shark's course and depth—at times 1,500 feet below us—and record the temperature and light level of the water where it was swimming.

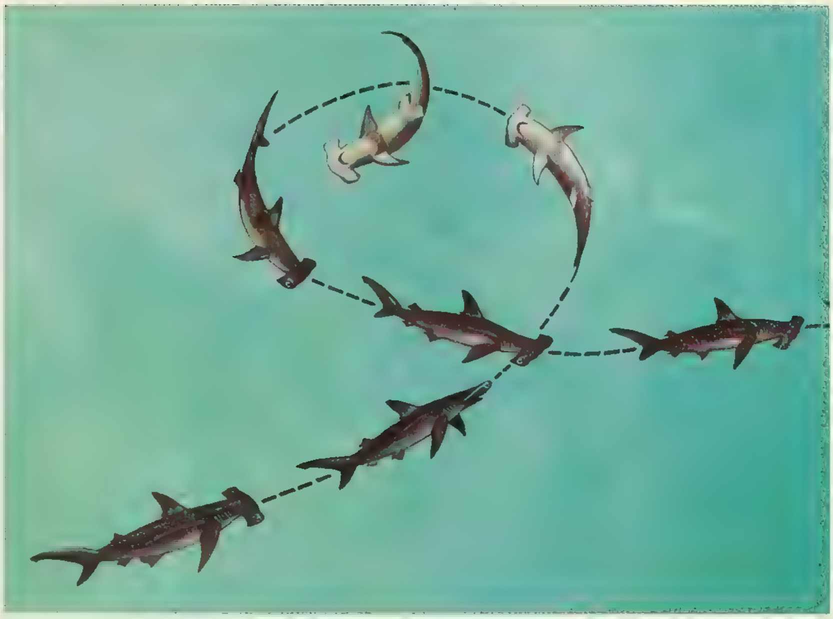
The first question, however, was whether the hammerheads were using the seamount strictly as a mating ground. If so, all the sharks in the school should be sexually mature. But I didn't know how to identify a shark that was ready to mate. Aided by local fishermen who allowed me to examine their catches, I measured dead sharks and examined their sex organs. Maturity in male hammerheads is signaled by the size of their "claspers," or male reproductive organs, while mature females have full-sized ovaries. Using these standards, we determined that males mature at about five and a third feet in length, while females must reach seven feet or more.

Next, I measured the sharks in the Espiritu Santo school. A diver cannot hold a ruler to a swimming hammerhead, however, so I tried three-dimensional photography. A metal pole with a crossbeam that had a camera mounted at each end—with linked shutter releases—enabled me to shoot stereoscopic images. Under high magnification I could measure the differences between the right and left photos and calculate the actual length of a shark. One female scalloped hammerhead—the largest I photographed—was a full thirteen feet long.

What I learned from all this measuring (and from hundreds of hours of direct observation) was that although mating did occur at the seamount, the school was not simply a mating aggregation. Females outnumbered males in the school by about six to one. But while the males were generally larger than five and a half feet, and thus sexually mature, most of the females were too immature—many were as small as three and a half feet—to be ready to mate.

From my first contact, I had noticed that hammerhead shark aggregations, unlike schools of small bony fishes, contain individuals of many sizes, haphazardly spaced and swimming in uncoordinated patterns. Large females cluster at the school's center, while the smaller ones swim at its edges—a distribution that is established and maintained by constant fighting. Dominant females strike subordinates with the undersides of their jaws, often leaving white abrasions near the head. Also, they bully their rivals by performing a threatening "corkscrew" display—a maneuver resembling a reverse somersault with a full twist. A female accelerates into a tight, looping trajectory while rotating her torso almost completely. As she spins, a bright flash of light reflects off her white belly, providing a dramatic highlight. Upon observing a large female's corkscrew, subordinate females withdraw to the school's edges, swimming away quickly and sometimes shaking their heads.

Females that win a central position in the school become the most desirable to males. A confident, sexually mature male will dash into the central cluster while performing a "torso thrust" to advertise his readiness to mate with a "boss" female. By beating his tail to one side, he propels his midsection to the opposite side, revealing his clasper. If a female accepts him, the couple leave the school and swim to the bottom of the seamount, where they may mate. Thus, one function of hammerhead schooling is indeed reproduction; the females' social dominance system enables males to quickly locate the most reproductively desirable mates—a task not easily accomplished when the sharks are wandering as individuals in the open ocean.



A large female hammerhead can intimidate smaller ones with an acrobatic maneuver called the corkscrew display. The animal performs a reverse somersault while rotating her torso, producing a momentary flash of light off her white belly. Using this display—and by striking subordinates with her jaws—a dominant female can establish her position in the center of the school.
Richard Ellis

But the seamounts serve as more than a social center. Years of tracking the movements of tagged hammerheads have persuaded me that seamounts are navigational centers as well. Each evening around dusk, the hammerheads begin a ten- to fifteen-mile swim from Espiritu Santo, always returning by dawn on the following day. Apparently, they spend the night at distant, deep-water feeding grounds (sometimes at other seamounts) preying on squid.

The hammerheads' nightly round trip is an extraordinary feat of navigation because they swim neither near the surface (where they might orient themselves by the moon or stars) nor at the bottom (where they might find their way by following the sea floor's topography) but make their way on a fixed course, oscillating like yo-yos from higher to lower depths. Transmitters fitted with miniature compasses relayed the course of tracked individuals to our instruments at the surface. At times, the hammerheads swam with consistent directionality, like cars following along a highway. When they reached the outermost point in their course, they seemed to stay in the same area and make jerky, random movements—presumably while feeding. In the case of one individual, we were able to determine that the animal's path ended at a distant seamount where squids gathered in great numbers.

Much later we discovered that while still young, female hammerheads leave the coastal shallows of their infancy to join the schools. Using the seamount as a navigational center, they are able to find their way to deep waters where nutritious squid and fish abound, and then return to the school. This rich diet promotes rapid growth, and females can soon reach the seven-foot size necessary for nourishing em-

Large females bully smaller ones with intimidating displays to win their places at the school's center.

bryos, which may make up a third of a pregnant female's weight. By examining the stomach contents of dead hammerheads, we found that only a few species of squid—none of them found in the sharks' seamount area—make up more than half of the hammerheads' diet and seem to be their major prey. (All these squid are about one and a half feet long, and one species is bioluminescent. That might account for the flashes of light that registered on some of our sharks' implanted light sensors during nocturnal forays.)

When returning from their distant feeding grounds to their home seamount, the sharks often used paths that coincided with their outward-bound route. Were the sharks using ocean currents to retrace their outward movements? I believed that would be unlikely, since currents constantly change speed and direction. But the frequent use of the same paths (particularly by one hammerhead we tracked for nine days) led me to investigate two permanent features in the sharks' environment: the topography of the ocean floor and the local magnetic field. When I found no correlation between the physical topography and the sharks' movements, I focused my attention on the invisible magnetic landscape.

The sea floor is magnetized along a north–south axis, but seamounts and volcanic islands are like big dipolar magnets, interrupting the larger pattern. Where molten lava seeped up through cracks in the sea floor, rises and falls in magnetic intensity now form invisible "ridges" and "valleys," which serve as "roads." Some fan away from the seamounts like spokes from the center of a wheel, and could be used by the sharks to make their nightly foraging trips. Analysis of the sea floor also revealed alternating strong and weak bands of magnetization that were formed during its geological development. These "roads" leading north and south might be used by marine animals to navigate between temperate and tropical seas, with seamounts as rest stations along the way. Scalloped hammerheads, although somewhat migratory, prefer to stay in tropical waters and are usually caught south of the Gulf of California during the winter months, when the gulf waters grow cool.

We conducted a geomagnetic survey with a magnetometer towed behind our research vessel, in a pattern of increasingly larger circles, around the seamount. By comparing these readings with measurements from a stationary magnetometer on the seamount, we were able to isolate the normal, daily variability in the area's magnetic field. When we superimposed computer maps of the paths taken by sharks upon maps of bottom depth and magnetic-field intensity, a clear pattern emerged. Espiritu Santo was at the edge of a strong magnetic "plateau" that sloped to an area of low magnetic intensity. Hammerheads moved either along the edge of this invisible plateau or along magnetic ridges and valleys. After further examinations of our maps, it became evident that hammerheads always moved along the edges of steep rises or falls in magnetic intensity.

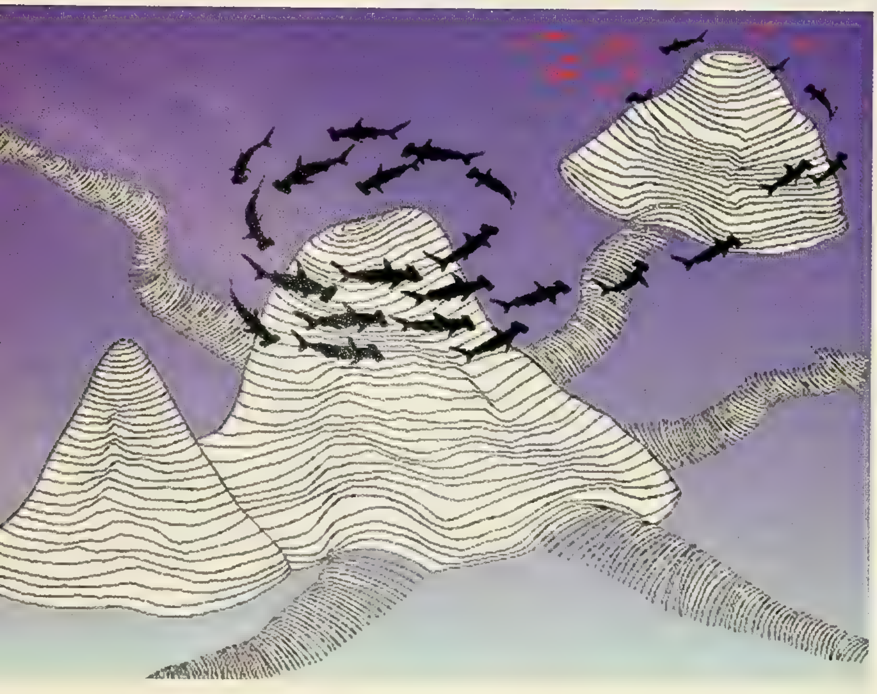
Although little is known about the relationships of marine animals' movements to patterns of sea floor magnetization, there is evidence that various species of animals do make use of these fields. Joe Kirschvink, of the California Institute of Technology, and his colleagues have shown, for example, that whales strand most frequently at points where bands of particularly strong and weak magnetization intersect the east coast of North America.

Although the magnetic gradients in the magnetization of the sea floor are quite small, many species of sharks and their close relatives, rays, respond to fields as low as a hundred-millionth of a volt per centimeter, making them the most sensitive electronic receptors in the animal kingdom. Indeed, Adrianus Kalmijn, of the Scripps Institution of Oceanography, demonstrated more than a decade ago that several species are so highly attuned to electromagnetic activity that they may well use it to detect their prey. In one classic experiment, he showed that sharks can easily find a flounder that has been sealed in an odor-proof box entirely by the prey's electrical activity (*see* "The Shark's Sixth Sense," by Adrianus Kalmijn, *Natural History,* March 1978, and "Why the Shark Bites," by Bruce Stutz, *Natural History,* November 1987).

The most likely manner in which sharks sense minute electromagnetic differences has also been proposed by Kalmijn. He theorized that a shark induces an electrical current when it swims across lines of magnetic force. This creates a voltage differential between receptor cells—called the ampullae of Lorenzini—located on either side of the shark's snout, which enables the

Seamounts seem to be the hubs around which large schools of hammerheads cluster. Invisible magnetic "valleys" and "ridges" radiate from these geological formations like spokes of a wheel. Following these roads, the hammerheads travel to distant feeding grounds to gorge on squid each night and return to their home bases at dawn.

Richard Ellis



Paul Humann; Jeff Rotman Photograhy

Hammerheads follow electromagnetic “roads” from their undersea mountains to distant feeding grounds and back again.

animal to make sensory comparisons between the two sides. Just as a snake uses its forked tongue as a guide, the hammerhead may use comparison of sensory information from separated right and left sides to follow invisible trails through twists and turns (*see* "The Serpent's Tongue," by Kurt Schwenk, *Natural History,* April 1995).

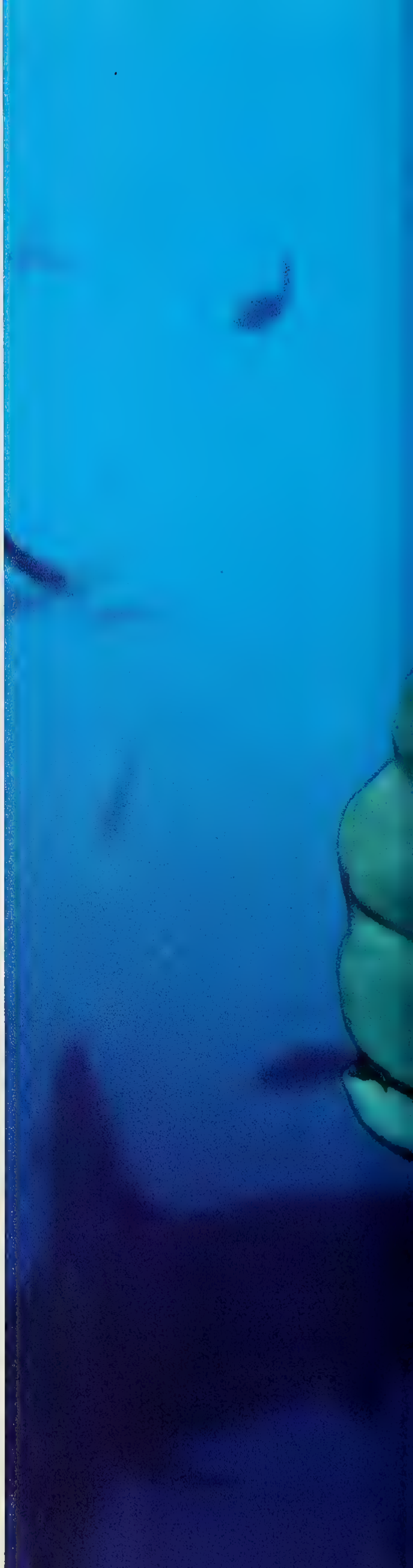
These sharks may be comparing voltage input from the right and left sides of their extraordinarily wide heads.

Could the hammerhead's marvelous sensory ability be due to its extraordinarily wide head, providing maximum separation between the magnetic receptors? I think so. By holding constant the magnetic intensity perceived as a voltage differential between the ampullae on either side of its head, the hammerhead could maintain a constant course. It may be able to easily follow magnetic ridges and valleys by swimming in the direction of the change it perceives in voltage. The reason for the shark's yo-yo-like swimming movements, therefore, may be a constant up-and-down scanning to distinguish the local magnetic fields that give them their navigational guidelines.

The actual mechanisms behind magnetic-field navigation remain unclear, but new evidence is accumulating. In one study, Joe Kirschvink suggested that some animals might sense changes in magnetic fields through minute movements of particles of magnetite embedded within their tissues. Although no one has yet looked for magnetite in sharks, chains of these particles have been found in the tissues of salmon, another ocean migrator.

In experiments I will soon perform in the ocean, near the Bodega Bay Research Station in northern California, a large Y-maze, currently under construction, will test the electrosensing abilities of sharks and rays. By training them to follow electric cables buried underground to a food source, I believe we will be able to manipulate their navigational paths. (Some other species of sharks did attack and sever "live" communications cables in the deep ocean during the 1980s, apparently mistaking them for prey, which cost the telephone company $250,000 per splice.) If we wound sufficient wire cable around a seamount, or dumped a few tons of magnetic ore on it, could we modify the field enough to fool the hammerheads and, perhaps, the local assemblage of fish into moving elsewhere? Could artificial electromagnetic "roads" be used to harvest certain fish? Might such a selective technology replace today's wasteful drift-net fishing, which scoops up every living creature for miles?

One can imagine such possibilities, but I'm not seeking immediate practical results from my work; I'm just lucky to be able to pursue my curiosity about other creatures' lives. And while we still have much more to learn from scalloped hammerheads, I believe they have already revealed some answers to why seamounts are the centers of their world. □



Scalloped hammerheads are named for the patterns along their wide snouts.

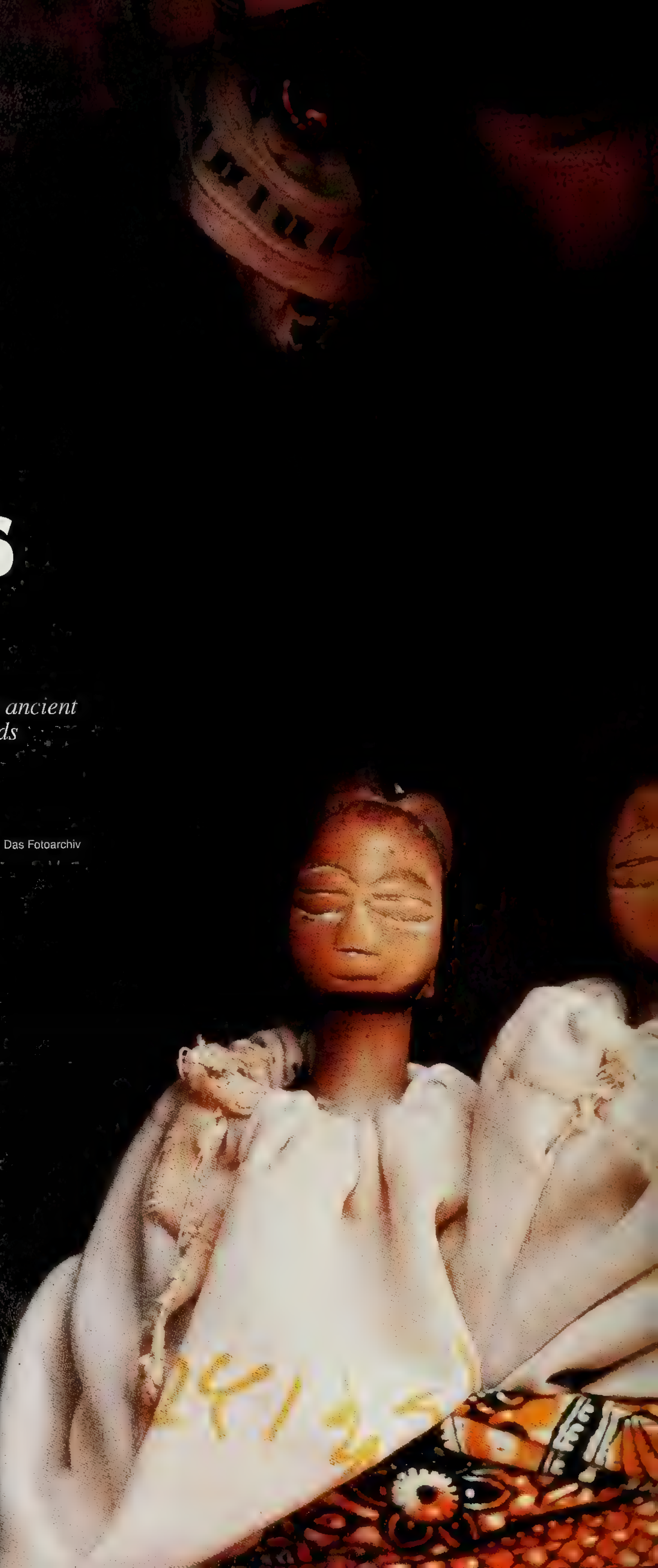
The Place Where Vodun Was Born

At a West African crossroads, devotees of an ancient religion welcome each appearance of the gods

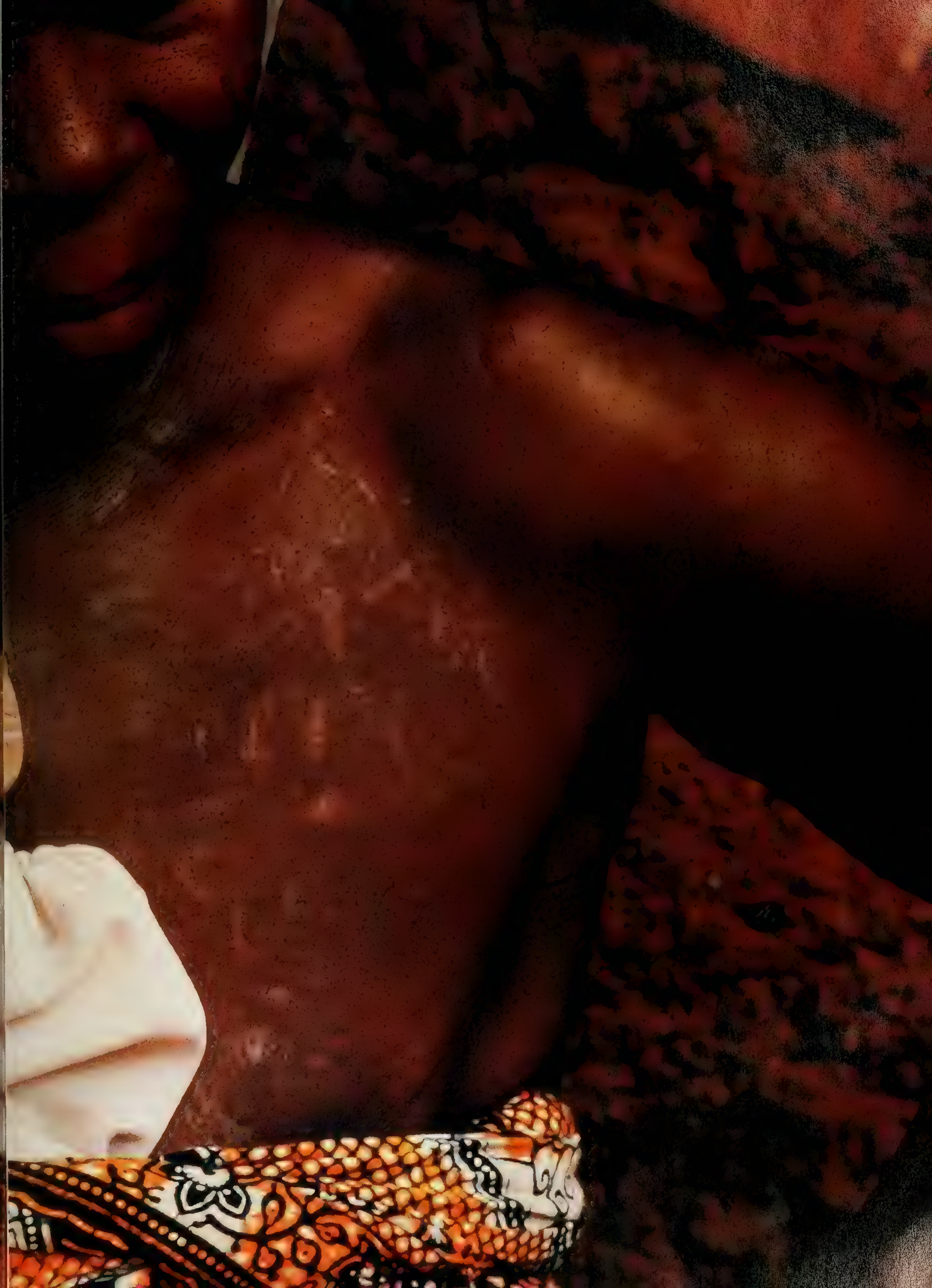
by Suzanne Preston Blier

Photographs by Henning Christoph Das Fotoarchiv

In Benin, West Africa, Vodun permeates life. People come into the world through the auspices of a deity and live out their lives in a world filled with deities who connect the natural and material worlds to the worlds of the living and the dead. They inhabit the trees, the earth, the stones. Ask and you'll be told that not everything has a god, but listen long enough and you'll realize that the gods are everywhere. You couldn't begin to count the Vodun gods. There may be 2,000, there may be 200,000. Gu, the god of iron, serves as the god of cars. But the Gu



A woman commemorates dead twins by carrying wooden figures tucked in her dress. In Vodun, twins are considered to be gods.



In a ceremony seeking protection from malevolence, participants cut themselves with knives to show the power of Vodun.

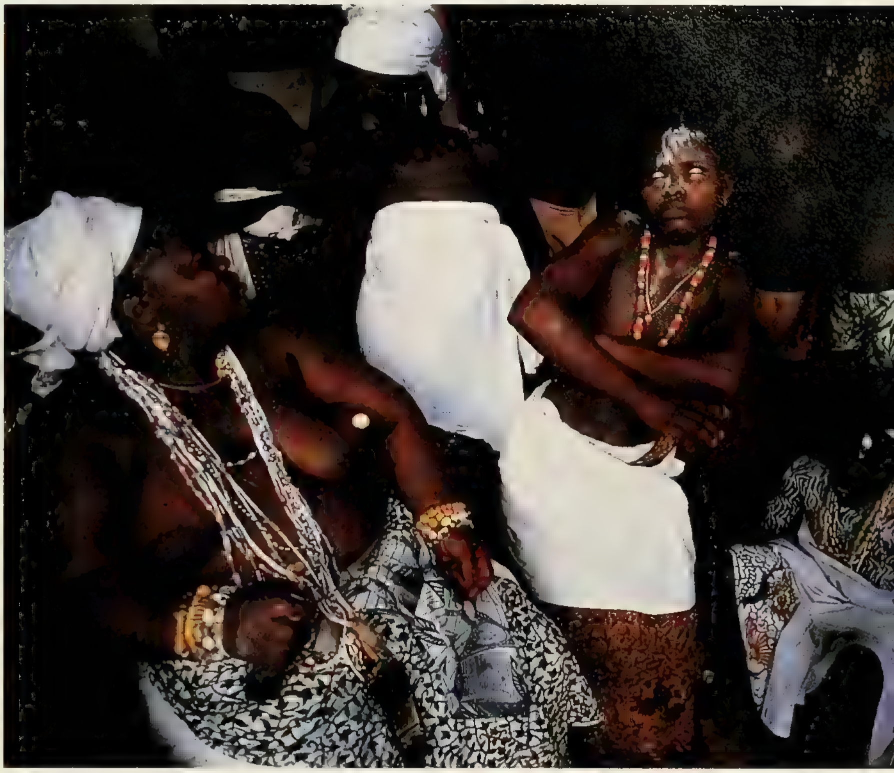
dwelling in your car would be different from the one dwelling in mine.

The gods are involved in everyday life: they settle arguments and take offerings to allay illness, relieve curses, or bring luck. Legba, the messenger god, is enshrined in front of every house. The various offerings to the gods must be mediated through this youngest of them. Take a look at a representation of Legba in a diviner's home; the god may be wearing sunglasses, an appropriate accessory because Legba is the trickster god, always inscrutable. He may deliver the message; he may not.

Vodun recognizes the complex layering of phenomena. A characteristic of every shrine—anything from a refined piece of sculpture to a simple earthern mound—is that the material of its construction becomes a metaphor for the connectedness of things. Wet earth is mixed with plant leaves, with colored beads, with bits of metal, with patches of cloth, with the blood of animals; all the components are pulverized so that they are enmeshed within the whole to become a symbol of the deity's identity and character.

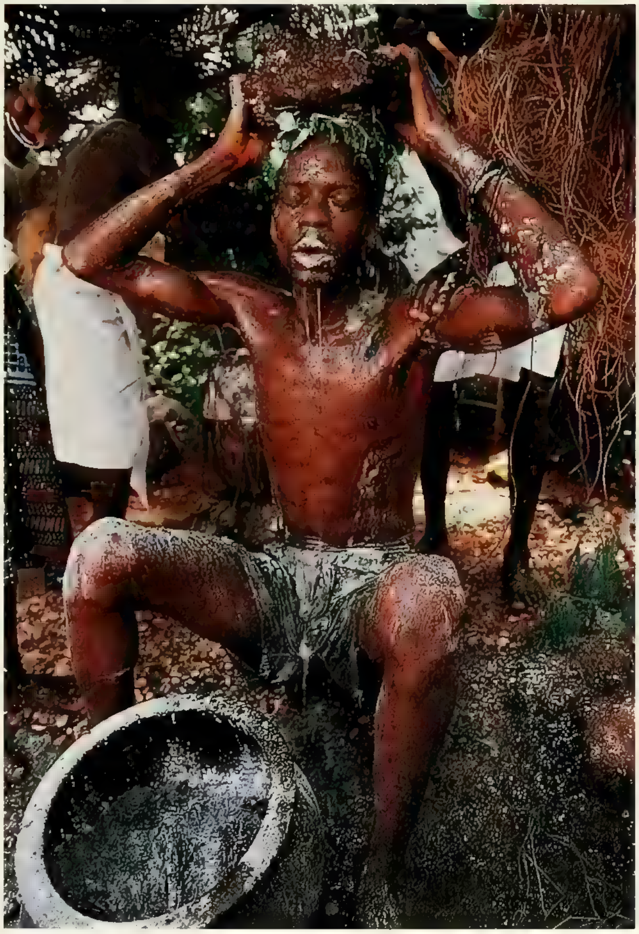
Rooted in ancient beliefs, Vodun (or Voudou, as it is known in the Americas) was born in what is now southern Benin and nearby Togo, on the Gulf of Guinea. Lying on the coastal route between rain forest and savanna, the region has been a crossroads of the Fon, Ewe, and Gun cul-

The rites of Vodun are emotional experiences designed to provoke responses from the gods.



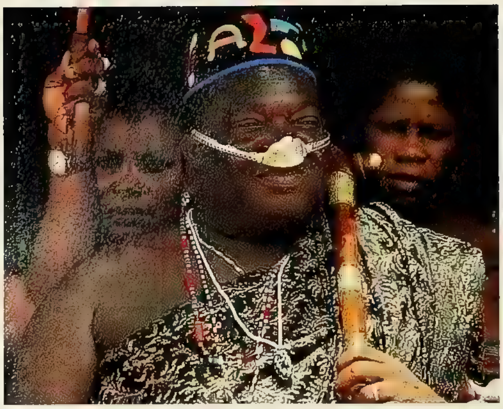
tures, among others. Beginning in the fifteenth century, the variegated nature of Vodun was further intensified as a result of the European slave trade, when captives from many West African cultures passed through the region on their way to the slave ships.

This part of West Africa was ruled by successive kingdoms, including Allada and, beginning in about 1700, Dahomey. The Dahomey king Guezo, who reigned from 1818 to 1858, demonstrated the inclusiveness of Dahomey culture when he ordered a shipment of Vodun sculptures from Europe. What he acquired were actually representations of Roman Catholic saints—Saint Roche, Saint Laurent, and



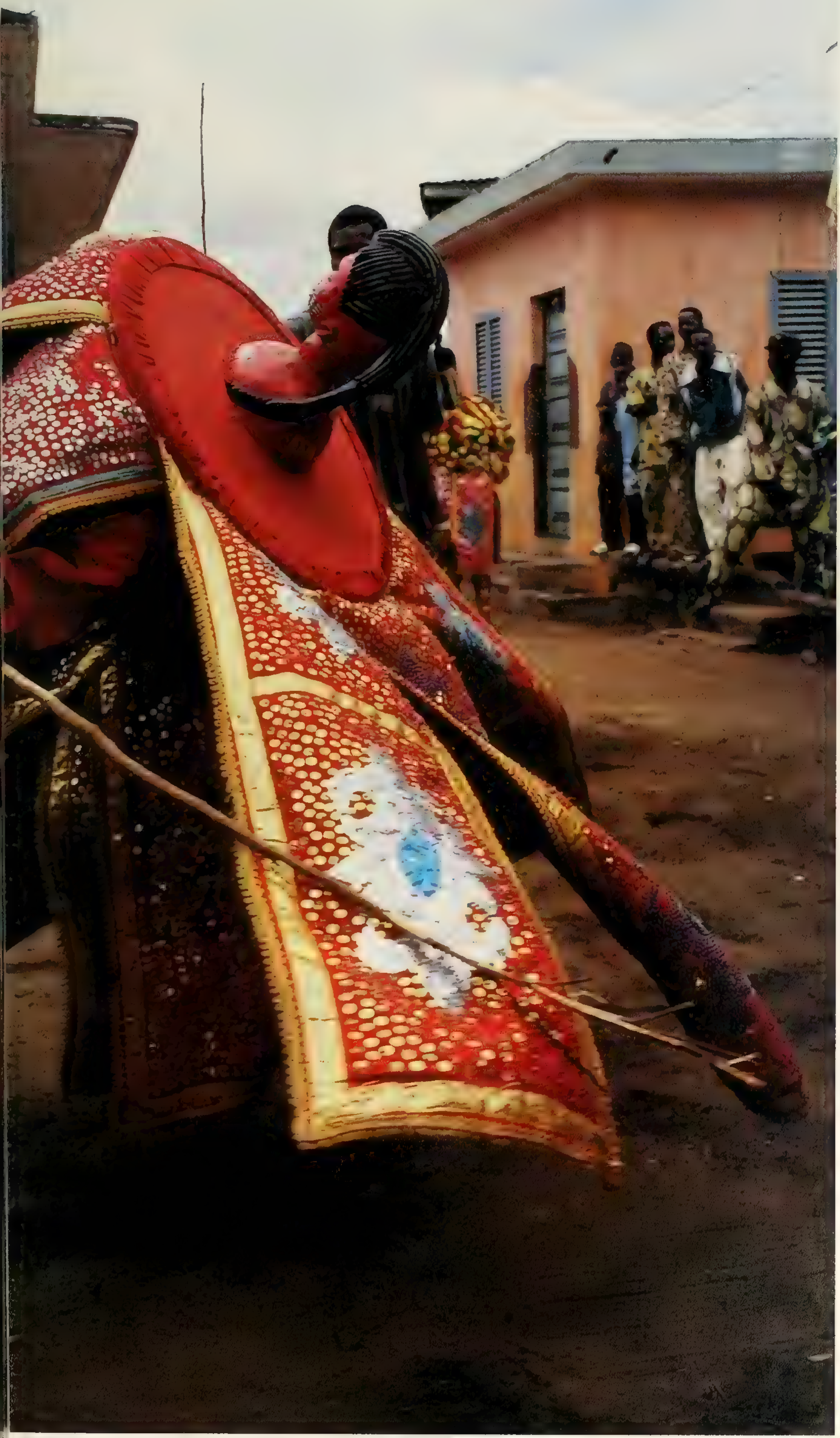
Observed by a priestess, above, a woman dances in a deep trance. She is a devotee of Mami-Wata, a "mother of the waters" who can summon health and well-being. A man suffering high fever and pain, left, is bathed with herbs to wash away a curse.

The natural world—herbs, wine, perfumes, decoctions of leaves or bark, pastes of blood and ashes—is brought to bear on the spiritual realm.



others. These ultimately served as models for some of the most visually powerful royal Vodun sculptures. Another example of Vodun's adaptable iconography is the cult of Mami-Wata, familiar to people all along the coast of West Africa. The cult had its origins in a poster portraying a touring circus performer from Hamburg who advertised herself as an Indian snake dancer. The poster appeared all over West Africa, and her image became a prominent and powerful symbol for women, representing a "mother of the waters," who could summon health and well-being.

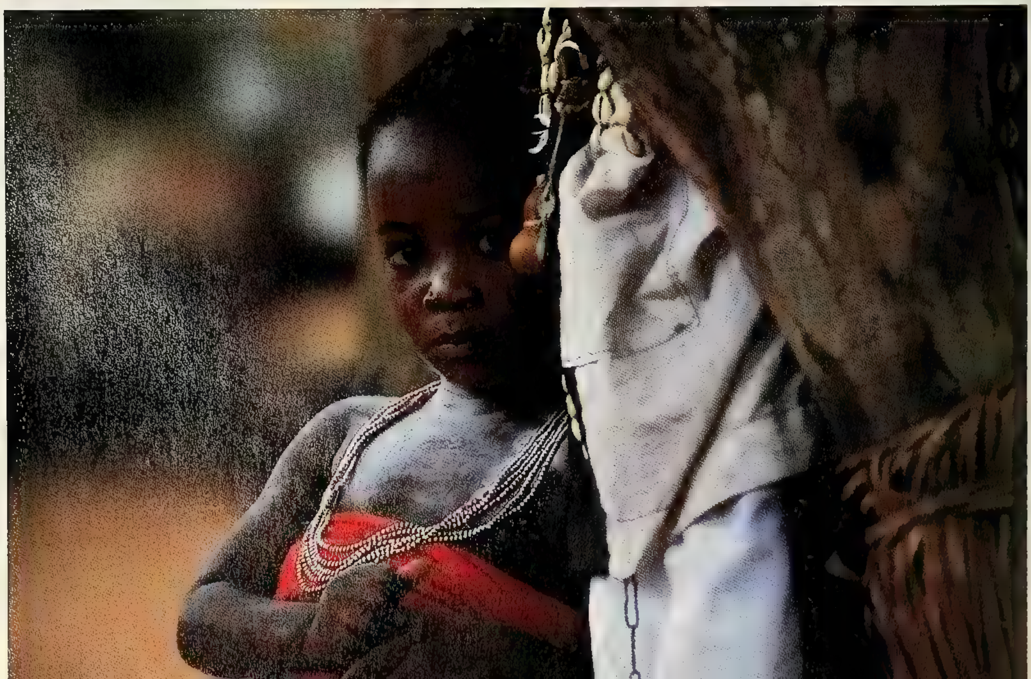
The term *vodun* first appeared in print in 1658 in the *Doctrina Christiana,* a work by the ambassador of the king of Allada to the court of Spain. In this work, *vodun* generally is translated as "god" or "sacred." Although the puzzle over the word's etymology remains unresolved, two diviners I met during my time in Benin both told me that *vo* means "to rest" and *dun,* "to draw water." They explained that "in

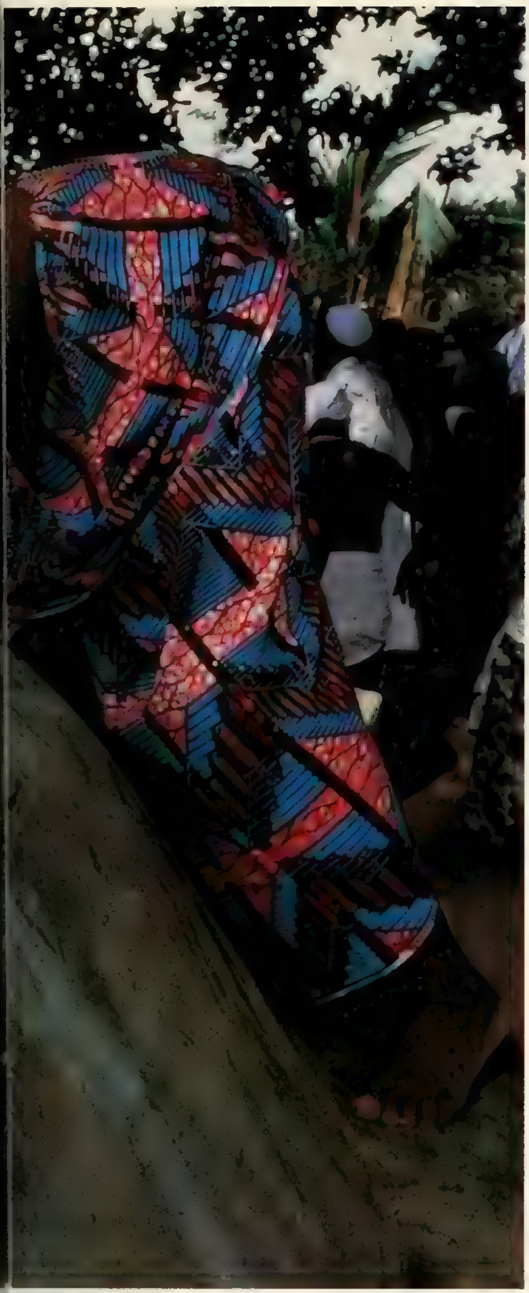


At an annual celebration honoring Yoruba ancestors, left, a dancer in southeastern Benin performs an Egungun dance. Above: Herbs and other ritual materials are set out on a platter. Far left, top: His Majesty Dedjalagni Agoli-Agbo, king of Dahomey, wears a silver sieve shaped like a leopard's nose as protection against breathing dust. Far left, bottom: Followers of Vodun perform a rite to counteract witchcraft.

In a trance, a Mami-Wata devotee, right, climbs on a village shrine to obtain its power. A child, below, watches a ritual from the sidelines. Far right, top: A Vodun priest in his temple pays respect to the gods. Far right, bottom: Chicken blood is offered to various deities at a shrine for Sagbata, god of the earth, whirlwinds, and disease.

The deities dwell everywhere, connecting the material world to the worlds of the living and the dead.

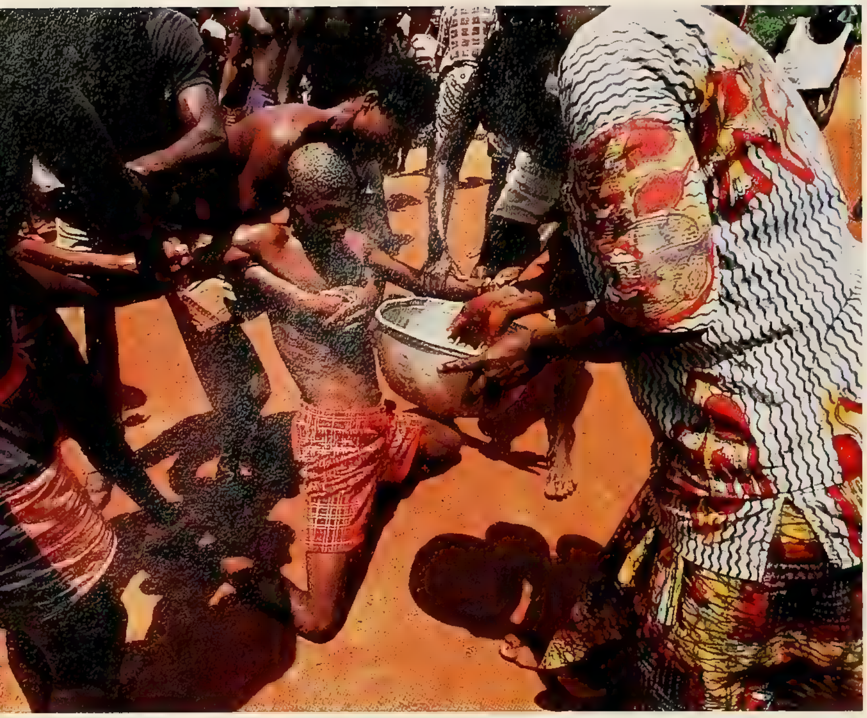




this life, there is a pool that is below, and one draws from it," but "one should rest before drawing." For devotees, the essence of Vodun resides in ideas of calmness and composure. When women go to the spring or river to draw the daily water, they rest for a moment on the bank before filling their containers.

Vodun teaches that one must take time to sit quietly rather than rush through life. One should accept the flow of events. Even at funerals, relatives are chastised if they cry: outward signs of emotion are taken to be evidence of frailty and loss of control. Only during religious possession and war is it considered appropriate to display emotion.

The rites of Vodun I observed were emotional experiences designed to provoke responses from the gods. Just as an amalgam of materials is used to represent the external world in a Vodun sculpture, so in religious practice the natural world of things—herbs, wine, perfumes, decoctions of leaves or bark, pastes of blood and ashes, each thing a dwelling place of gods—is brought to bear upon the spiritual realm. The resultant ritual can be as mundane as dropping a bit of food on the ground before one eats as an offering to the ancestors, or it can be as elaborate as coating the body with pastes designed to turn the worshiper into a living Vodun sculpture. It can be as heated and intense



A Vodun devotee in a trance, above, is washed with palm wine and herbs. Another devotee, right, is assisted in his trance.

"In this life, there is a pool that is below, and one draws from it."

as dancing to the driving beat of a drum in order to induce a hypnotic trance.

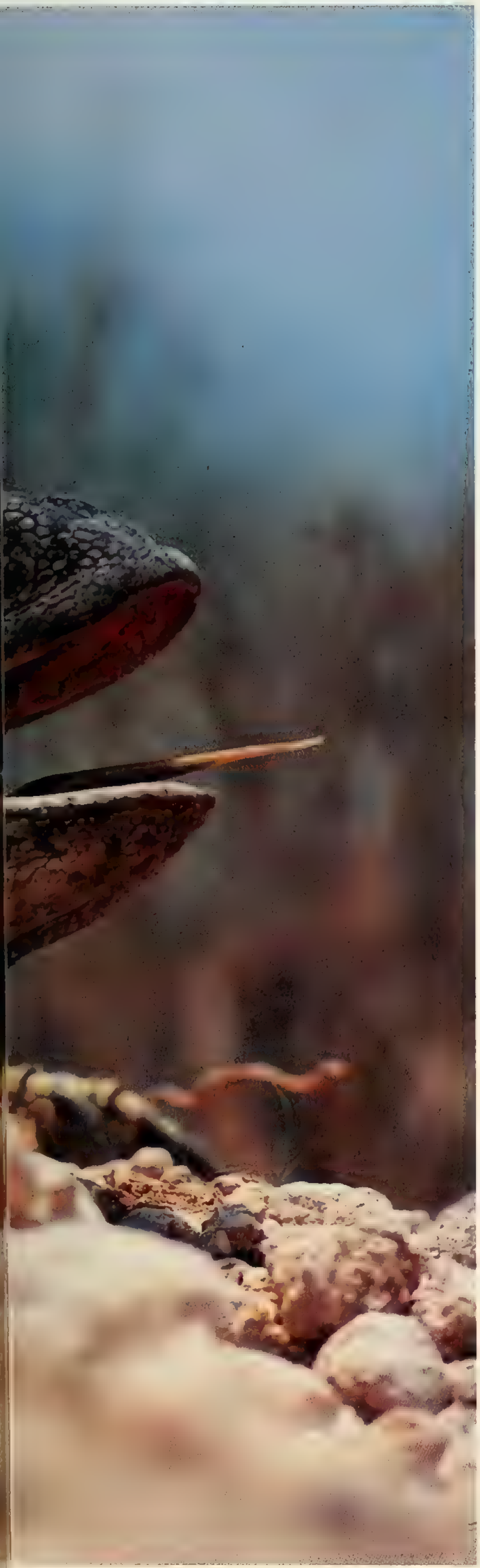
In one ritual I observed outside a temple of Sagbata—the god of the earth, whirlwinds, and disease—a devotee in a trance spun around and around, his acrobatic wheeling as beautiful to watch as it was difficult to perform. Another exuberant dancer balanced two straight-backed chairs precariously on his arms while moving his body into a series of angled positions. More dancers followed, in round-robin fashion, each devotee displaying the special acrobatic talent that the god Sagbata had accorded him. The emotionless faces and fixed, seemingly unseeing eyes of the trance dancers contrasted with their taut-muscled backs and limbs, glistening with sweat.

The dances both honored the gods and were believed to be brought on by them. Because this was a sacred event, the audience of family members, together with other villagers and cult members, watched spellbound, in complete silence, neither clapping nor offering verbal encouragement or praise.

After an hour, when each dancer had appeared several times, the drum beats ceased and the devotees of Sagbata went back inside the temple. With the departure of the dancers, the other villagers returned to their daily activities, knowing that they had once more been blessed by an appearance of the gods. □

Rhythms

# of a Desert Lizard



For four months, the white-throated monitor of Namibia inhabits a land of plenty; the rest of the year, it fasts

by John A. Phillips

Alfred Brown, an English immigrant to South Africa in the second half of the nineteenth century, was fascinated by large lizards, living and extinct. Officially, Brown was schoolmaster, as well as postmaster and librarian, of Aliwal North, a small frontier town northeast of Cape Town. Unofficially, he was Gogga ("vermin" in Afrikaans) Brown, the town's ardent, almost pathological, naturalist.

Between 1869 and 1909, Gogga Brown produced 10,000 pages of neat, handwritten notes on subjects ranging from meteorology to archeology, geology, and paleontology. But his most passionate interest by far was the local species of monitor lizard, the white-throated monitor, or leguaan (an English language corruption of the Afrikaans word, from the Portuguese *l'iguana*). In an era when scientists pickled animal specimens first and described them later, Brown was something of an exception. He spent the better part of his life attempting to piece together a complete life history of the leguaan, one of four monitor lizards in Africa and a species he felt provided insight into the dinosaurs.

A relative of the formidable Komodo dragon, the five-and-a-half-foot-long white-throated monitor, or leguaan, is a voracious carnivore.

Cataloging the biology of this fifteen-pound-plus, five-and-a-half-foot-long, voracious carnivore—a relative of the formidable Komodo dragon—was no easy task. The harshness of the rocky terrain and thorn-scrub vegetation around Aliwal North, coupled with the animal's ability to travel several miles a day, made it extremely difficult to observe the lizards in the wild. To circumvent this problem, the industrious Brown constructed an elaborate vivarium that housed up to forty-two lizards at a time. During the many years of his studies, he kept and cared for more than 200 leguaans.

Brown fed his charges top-quality food. From the wild, he collected smaller lizards, amphibians, birds, locusts, and dead snakes. In addition, he fed his leguaans chicken eggs and meat from slaughtered farm animals. At night, especially during the cooler winter months, he covered each animal with a blanket. Such extravagance apparently consumed the better portion of Brown's meager salary, but his close attention to

The gaping mouth of an adult leguaan, left, warns of possible attack.

John A. Phillips

Searching for prey, an adult leguaan, above, swings its head from side to side and flicks its tongue to pick up scents in the air.

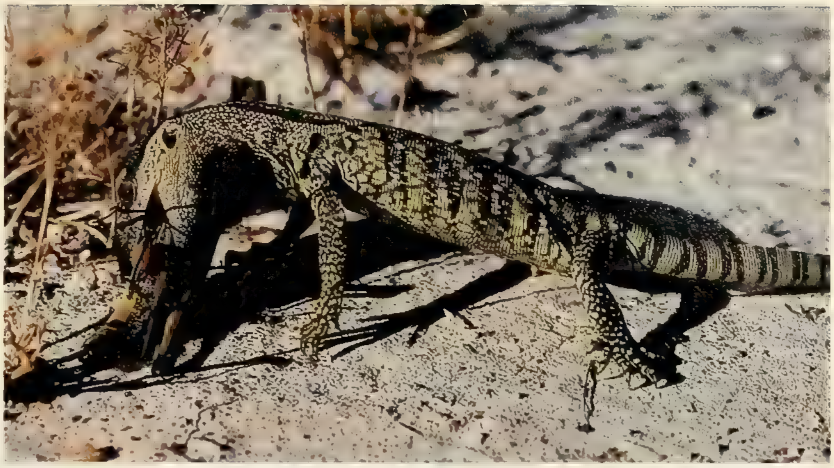
C. Haagner; Bruce Coleman, Inc.

the animals produced outstanding results. He recorded information on size, sex ratio, body proportions, morphology, diet, and behavior. He studied the relationship between food consumption and fat deposition, as well as how the animals regulated their body temperature. And although he could not follow the monitors closely in the wild, he knew from his walks what their preferred habitat was. Not until the 1940s would professional herpetologists match his discoveries, in part because the reclusive Brown kept his observations largely to himself, and in part because when he did send his manuscripts to scientists at European museums, they were ignored.

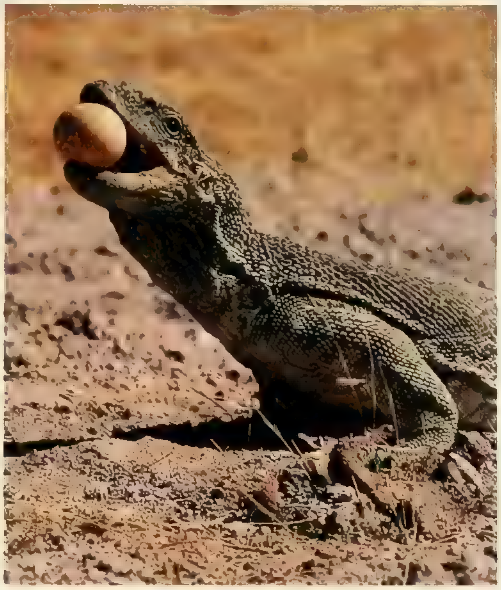
Despite his many accomplishments, Brown became disheartened. Quite simply, he had the will, but the technologies of the nineteenth century defeated him. Without modern incubators, he failed to hatch eggs, and without radiotelemetry or other sophisticated equipment, he was unable to track individuals. His neighbors also hindered his efforts. Far from sharing Brown's desire to understand leguaans, local farmers killed the animals for their skins, which they sold to local cobbler shops. A heading in his notes reads: "The monitors, destruction of by certain persons." Because of these disappointments, and perhaps also because of ridicule at the hands of his neighbors, Gogga grew even more reclusive in his later years, and his passion for studying the leguaan waned.

I first heard of Alfred Brown in 1990, from Bill Branch of South Africa's Port Elizabeth Museum. Listening to Bill by the light of the campfire at my field site, I was impressed by Gogga's data but saddened by the thought of what must have been a very lonely existence. I felt fortunate to have twentieth-century technology on my side, enabling me to concentrate my studies in Namibia's Etosha National Park on monitor lizards in the wild.

The floor of a large, shallow inland lake that dried up sometime during the last 12 million years, Etosha is flat and ideal for radio tracking animals. The semiarid landscape undergoes its annual renewal during the hot, wet season, from December to March. With new plant growth, the animal populations, from insects to elephants, flourish. Leguaan biology, like that of other animals in the Etosha area, is based on this four-month period of feast and the subsequent eight months of famine.



Both photographs by John A. Phillips



A big-headed hatchling, above, tackles a grasshopper nearly half its size. Adult leguaans can eat a hundred grasshoppers at a time, following up, perhaps, with a bird egg, left.

Monitor lizards such as the leguaan are exceptional walkers when compared with similar-sized iguanid lizards. Like their food, herbivorous iguanas move little, but monitors are active predators. Male lizards travel over home ranges that average about ten square miles; females roam over areas about a third that size.

During the rainy season, a leguaan scours its home range for prey, covering two to four miles a day. With unblinking eyes and a long, forked tongue flicking the ground and air, it checks for the slightest movement or faintest scent. Either will cause the lizard to freeze—almost like a pointer—and then, after a few seconds, to attack.

Leguaans eat whatever they can catch and swallow. When the rains come, the lizards gorge themselves: 100 snails one day, 200 grasshoppers or perhaps an entire, four-foot sand snake another day, plus beetles, crickets, bird eggs, birds, and once in a great while, a small mammal. Such hearty meals are not exceptional for monitor lizards. Juvenile lace goannas (Australian monitor lizards) weighing only about three pounds can eat rabbits weighing a pound. The Komodo dragon, largest of the monitors, has been known to kill water buffalo.

Voracious appetites are not restricted to adult leguaans. Each year, after incubating for about four months in an underground nest, hatchlings emerge about midway through the wet season. A hatchling's disproportionately large head is wider than its body and, at one inch, more than a quarter of its entire body length (excluding the tail). Thus, it can swallow prey about as big as it is. But while chasing prey, hatchlings are themselves at risk of becoming a meal for the many raptors and snakes in Etosha. Their keen sense of vision and olfaction help many hatchlings survive. With a single flick of the tongue, for example, and at a considerable distance, hatchlings can pick up chemical cues in the environment, enabling their olfactory system to distinguish venomous from nonvenomous snakes. And like adults, they can spot potentially dangerous flying objects at enormous distances. I have seen hatchlings track the path of a jet plane flying 35,000 feet above them. But the odds against them are great, and less than a third of them make it through their first wet season.

By May, when the rains and warm days are but a memory, the survivors have doubled their hatching weight. With the once-lush vegetation

During the rainy season, leguaans may walk several miles a day, gorging on everything from snails to snakes.

White-throated monitors, right, spend part of every day basking in the sun. Far right: The Nile monitor lives in many of the same parts of Africa as the white-throat, but it sticks close to rivers, where it swims propelled by its long tail.
John A. Phillips

When the rains cease, the leguaans stop moving about. One large male stayed in the same tree for seventy-three days.

turning brown and yellow, the number of insects, snails, and other prey declining, and temperatures dropping, the leguaans stop moving about. For the next three months, the lizards—young and old—conserve energy by staying remarkably still, relying for survival on fat stored in their bodies. The largest male I ever tracked remained in a tree for seventy-three consecutive days, sometimes moving from branch to branch, but apparently never leaving the tree.

Exceptions to this rule are individuals that have stumbled onto a large cache of food toward the end of the rainy season. One large male took up residence in an abandoned sociable weaverbird nest that was also home to a pair of barn owls. Because rodents were plentiful that year, the owls had produced a second clutch of five hatchlings in May. As the owlets grew, the leguaan would devour one, travel about for a few days, then return to the nest for another meal. The lizard apparently never caused a major disturbance in the nest: the adult owls continued to care for the remaining owlets up until the day the lizard ate the last one.

In late July, as if startled into action by an alarm clock, adult male leguaans begin moving about their home ranges at a frenetic pace. As in the wet season, trips of two, three, and four miles a day are common, but at this time of year there is absolutely nothing for them to eat. The reason for their seemingly obsessive movements? The females have entered estrus. Each male is in a rush to reach all the females within his home range while they are still sexually receptive (estrus lasts only a week or two) and before any other males in the area find them.

Since the females are often widely separated, this is a challenge for the males. Fortunately, the females help out. As if waiting for suitors, each one remains nearly stationary in her home range and advertises her whereabouts and reproductive condition from a prominent tree. The sight of her is not what attracts the males; they are drawn, from as far as a mile away, by an as-yet-unidentified pheromone.

About five weeks after mating, the female lays about 50 one- to two-ounce eggs. Not having eaten for four months, she has to dig deeply into her own fat, protein, and mineral reserves to provision them. After laying her eggs, a female may be reduced to eight pounds from the fifteen or so that she weighed at the end of the rainy season. And she still has two months to go before she will find food again.

Tim Flannery, of the Australian Museum, has

Jeremy Woodhouse; DRK Photos

theorized that because they require far fewer calories to maintain their ectothermic life style, large, carnivorous reptiles are better suited to arid environments than are warmblooded mammals of the same size (*see* "The Case of the Missing Meat Eaters," *Natural History,* June 1993). Following this logic, one would expect that as a group, carnivorous reptiles in relatively impoverished environments, such as Etosha and much of Australia, should outweigh, in pounds per acre, their mammalian counterparts. By tracking all the male leguaans in an area during the mating period as they rushed from female to female, I was able to come up with a reasonably reliable estimate of the number of adults and subadults in Etosha. My findings bore out Flannery's prediction: in Etosha, the total mass of these 9,000 adult and subadult white-throated monitors would be close to 100,000 pounds, rivaling that of the park's lions and surpassing the combined weight of Etosha's cheetahs, jackals, hyenas, and leopards.

Gogga Brown never could have guessed just how successful his beloved leguaans had been. By the time he arrived, in 1869, farmers had killed off the large mammalian predators around Aliwal North. Sadly, outside protected areas, most species of monitor lizards in Africa are in decline today. Habitat loss is a factor, but the biggest threat facing these lizards is the skin and pet trade: several hundred thousand monitors a year wind up as shoe leather or in the pet store window. Still, there is reason for hope. Monitor lizards are adaptable, able to survive fairly well on farms and other lands altered by humans. If the skin and pet trade were strictly controlled, the white-throated monitor could continue its life of feast and famine well into the future. □

Rascals, Survivors

Once upon a time there was this guy who one day up and decided he wanted to be a filmmaker; he wanted to portray authentic, "real" ghetto life, which was noticeably absent from the silver screen. If you haven't guessed it already, the guy was me (we're talking circa the late fifties here), and I decided to start modestly—with a thirty-minute masterpiece. Accordingly, I had a friend who owned a camera point his lens at a number of scenes. I then spliced the footage together and projected my masterpiece on a sheet in the basement. It was all there. Everything we had shot came out as clear as a bell. Except it didn't say anything like what I was trying to say.

"It's all there, but it doesn't seem to make sense," I whined to my friend. "It doesn't say what I want it to."

"Not yet," he replied. "That's just the raw footage."

"What do I need to do?"

"Haven't you ever heard of editing?" he asked, incredulously.

"Of course I have," I lied.

"Well, same thing as making a piece of sculpture," my friend said. "A statue is only a slab of marble until you carve it."

Anyway, I bought a book about film and taught myself to edit. My half-hour epic dwindled to about eleven minutes. Not everyone agreed with me that it was a masterpiece, but at least it ended up making sense. Ergo, documentation and a documentary are not synonymous.

Early in the century, documentation was the urgent priority of anthropological filmmakers. Unique cultures, they feared, were being swept away by the tide of industrial civilization, leaving us with no cinematic record of their diversity. Nowadays, diversity is threatened by an accelerated blending process. The once-omnipotent forces of natural selection are being put on hold. In the near future, thanks to preemie incubators, the March of Dimes, bionic limbs, and jet engines, we will democratize "survival of the fittest," and soon we will all be blended into one big biologically and culturally homogenized milkshake of humanity.

But before you do too much handwringing over this vision of a puréed populace pouring through malls, chomping on Big Macs—run, walk, crawl to the nineteenth Margaret Mead Film and Video Festival (at the American Museum of Natural History, October 18 through 23). This year the festival, the only anthropological film festival in the United States, presents 58 films and videos culled from more than 400 entries. I guarantee there is enough diversity on display to put your heart at ease. Topics range from Soviet cosmonauts to female genital mutilation in Africa; from working-class slums in England to the first Australian Aborigine concert tenor.

Since Mead's time, the inexorable march of technology seems to have considerably widened the fellowship of ethnographic filmmakers. Now that the camcorder facilitates crayola anthropology, "everybody," as Jimmy Durante used to say, "wantsa get into the act!"

For an anthropologist suspicious of artifice, and with a populist bent, this cinematic democratization must seem heaven-sent. But just as advances in medicine, climate control, and global travel have their downsides, so do continued advances in cinematic technology, as some entries I sampled in this festival attest. It took billions of years for the elements created by the big bang (RNA or DNA singularly or in cahoots) to evolve from the primordial soup to ape, but it took only a mere 150,000 generations for us to go from wielding clubs to camcorders. Ever since baby-simple, "one-touch" video cameras made it possible for anyone to capture technically acceptable images, the once-stringent qualifications required of a filmmaker have become more and more relaxed.

There are inarguable benefits to a populist, indiscriminate, open camera eye: just ask Rodney King. However, in the rush to embrace universal image grabbing, we must beware of trivialization. There

From Byker, *by Amber Films*

reamers

A Preview by Melvin Van Peebles

must be some thought behind the lens, or at least somewhere in the process of preparing the film or video for viewing.

Also, too many of the festival's films seem to have a relentless determination to be of a "significant duration," hovering somewhere around an hour. One suspects that this length has less to do with context than with funding and getting one's film shown on commercial television. Another constant is that the festival's films tend to be too sober, many of them affecting a solemn demeanor, as if the filmmakers are equating anything approaching a giggle as, at best, a sign of lunacy and, at worst, not a serious candidate for a grant.

After sampling some of this year's entries, however, I came to the inescapable conclusion that, for better or worse, our species is still alive and kicking. We are still the same ol' ragtag band of rascals and dreamers, still tussling with the environment to survive, searching for equilibrium, for place (whatever that means), and when our bellies are full enough, moving on to the next priority, still trying to make sense of life, trying to transform that survival into meaningful existence.

I reviewed fifteen of the entries and, for convenience' sake, divided them into the following four categories suggested to me by the material.

Feel the continent closing in on you? Suffering from the Marshall McLuhan Global Village blues? I recommend a cup of Mead.

Fish out of Water

Pepper's Pow-Wow, by Sandy Osawa, is a portrait of Jim Pepper, a Kaw/Creek Native American who has created a funky fusion of jazz and Amerindian music. As a saxophonist, vocalist, and composer, Pepper has had a great influence on Native American music, especially with his classic "Witchi Tia To." Based on a Comanche peyote ceremony chant that Pepper heard his grandfather sing, the song became a top-40 hit in the United States.

From Harold, *by Steve Thomas*

In *Struggle and Success,* director Regge Life interviews African Americans living in Japan, all pondering the same dilemma: Does one choose perpetual second-class citizenship in his or her native land or live forever classified as a foreigner in Japan?

In *The Trials of Telo Rinpoche,* a child born in Philadelphia to parents from Kalymkia, India, is recognized by the Dalai Lama as a reincarnate lama. At the age of seven, he goes to India to be raised by Buddhist monks, occasionally returning to the States to hang out with his boyhood buddies. In one of the most haunting sequences of the current festival, a solitary figure, a plumpish young man in a saffron-colored parka thrown over his saffron robe—the Philly lama—wanders into frame in a desolate Kalmykian landscape. A thin, dingy line marks the horizon of a dull earth meeting the gray sky. Slowly, he meanders around a huge, barren field wondering aloud how he will ever get his temple built.

But the most unforgettable fish-out-of-water film is about Harold Blair, an Australian Aborigine concert singer, and it's a film I have chosen to discuss later, along with my other "festival favorites."

Playing the Cards You Are Dealt

Here the filmmakers focus on folks who are in special situations, or subcultures, and whose existence is defined outside the mainstream. In *Twitch and Shout,* we enter the world of Tourette's syndrome sufferers, whose spasmodic body movements and uncontrollable speech make them seem like bizarre misfits. We watch, fascinated, as they search for life, liberty, and normality (which they tend to equate with happiness) with a surprising degree of candor and success. In the aggregate, they even find self-satirizing joy as they dance (you guessed it) the Jerk at a party. The film was made with an insider's understanding by Laurel Chiten, who has the disorder herself.

A Forgotten People: The Sakhalin Koreans tells of another kind of outsider's group: a colony of Koreans who were conscripted by the Japanese during World War II to work as miners on Sakhalin, an island off the coast of Siberia. After the war, the island was turned over to the Russians—not much of an improvement for the Koreans. As one laborer taken to Sakhalin in 1943 puts it, "The Japanese worked us like horses. Then they went away, leaving us like worn-out shoes. We were abandoned people. So the Russians grabbed us." Director Dai Sil Kim-Gibson dutifully—too dutifully, actually—catalogs their harsh saga. We watch second-generation Sakhalin Koreans trying to make a new home on the island and the older Koreans trying to return to their native land.

Self-imposed exile is the theme of *Breaking Silence: The Story of the Sisters at DeSales Heights,* Susan Pointon's story of a 150-year-old convent in West Virginia that is on the verge of closing forever. Pointon interviews the twelve remaining sisters, many of them in their eighties and nineties, who are about to be forced into the world outside their cloister. Much of the footage is a monotonous litany about sheltered lives and impending doom. Pointon, like director Kim-Gibson, is "polite"—not wishing to intrude or to push beyond what the sisters choose to tell. The Sakhalin Koreans, however, seem more forthcoming. Nonetheless, some poignant moments punctuate the nuns' story. When one elderly sister dies, we see her lying in her coffin, "white as a camelia." The other nuns seem to envy her escape from a fate worse than death: having to face life outside the walls of their beloved convent.

Another subculture is explored (but not too deeply) in *The Morehouse Men,* filmed at Morehouse College in Atlanta, Georgia. Established in 1867 to teach the sons of ex-slaves to read and write, the school has a special tradition of imbuing black men with pride and purpose. But while the film purports to be a peek inside the walls of this "black Harvard," we experience little more in the film than the rhetoric and ritual of their orientation meetings and graduations and a public controversy over whether or not to invite a Black Muslim speaker. Left with the impression that we are seeing only what Morehouse wants us to see, we wish the filmmaker had been more probing about the larger context of racism in America, and we wonder if the graduates really expect that they will compete on a level playing field after graduation. After an hour, the viewer still feels like an outsider.

Femmes aux Yeux Ouverts ("Women with Open Eyes") was made by the Togolese filmmaker Anne-Laure Folly with the cooperation of women in four different countries (Burkina Faso, Mali, Senegal, and Benin). In each of the four countries, we are subjected to the same horrific catalog of Third World mistreatment of women. The film brims with good intentions but suffers from repetition of its major points. In an unforgettable segment, however, an old woman blithely offers to grab a little girl from a group playing nearby in order to perform a routine genital mutilation on her for the camera. The filmmaker politely demurs.

Perhaps the best film about people playing out the hand of their cultural circumstances is called *Byker,* the name of a neighborhood in a city in northeast England. But I'll get to it a bit later, in reviewing my favorites from the festival.

From A Forgotten People: The Sakhalin Koreans, *by Dai Sil Kim-Gibson*

Colonialism, Past and Present

In recent years, anthropologists have grown increasingly uneasy about the history of colonialism and have struggled to make amends for the damage inflicted by Western nations on Third World peoples. *Mother Dao the Turtlelike*, by Vincent Monnikendam, is composed entirely of old silent-film footage taken by Dutch colonials in Indonesia between 1912 and 1933. In gorgeously textured images transferred from old silver nitrate film stock, the native inhabitants toil in the tropical sun while the pith-helmeted Dutchmen strut around, playing their boss-man routines to the hilt. For irony's sake, a soundtrack of gentle indigenous music and poetry has been added.

Who says you can't go home again? *Sugar Slaves*, by Trevor Graham, is a mixture of archival and new footage blended into a story resembling a sort of South Seas *Roots*. Between 1863 and 1904, about 60,000 Pacific islanders were transported from Vanuatu and the Solomons to Queensland, Australia, to work the sugar plantations. After the introduction of a "white Australia policy," most were deported, but 20,000 of their descendants remain in north Queensland today. We witness a Pacific island family reunion that spans oceans and generations, as the grandchildren of the dislocated ethnic group recover their identities. Some are even able to visit the islands from which their families were taken and to reestablish exactly who they are. The shock is not how unusual but how familiar it all seems.

For anyone naive enough to believe that the exploitation of indigenous peoples has ended now that the minerals and forests are safely tucked in under multinational contracts, we have the film *Gene Hunters*. This documentary shows scientists prospecting for potential medical gold in the blood of genetically isolated tribes. On camera, a scientist in the field earnestly explains that his job involves pure research, to benefit all humankind. But back at the laboratory of the pharmaceutical giant Hoffmann-LaRoche, where the blood ends up, a researcher blurts out that there can be big bucks in their work. A member of the Guaymi tribe complains, "They have taken our land for banana plantations, now they want our blood." From pith helmets to DNA, *plus ça change. . . .*

From Sugar Slaves, *by Trevor Graham*

Four Favorites, and Why

Despite the dissimilarity in topics and approach, each of my favorites—through the mastery and artifice of good cinema—pulls us into its subject and transports us into the lives of its people. But artistry does not automatically equal deception. Each of my favorite four uses cinematic techniques, not to blur or distort reality, but to focus the thoughts and sentiments that allow us to enter a cultural world different from our own.

State of Weightlessness is a masterful mixture of training footage of Soviet astronauts with spectacular scenes taken in orbit and informal interviews with the returned cosmonauts. One of them admits to gazing down at the earth from space and realizing how anxious he was to get back home. Another confesses that he wished he could have opened the door and remained in space forever.

In *Harold,* Australian filmmaker Steve Thomas tells the story of Harold Blair, a talented Australian Aborigine whose extraordinary life became the focus of political, racial, and cross-cultural issues. Born on a tribal reserve in Queensland in 1924, Blair's Nelson Eddy-like tenor voice earned him a career on the concert stage. During the height of racial segregation tensions in Australia, he married a white woman, seemingly unaware of the storm that would provoke. *Harold* begins conventionally enough, like a bio-pic about a famous singer, utilizing obscure archival footage. But even the newsreels that celebrate his success ("He can't throw a boomerang, but this blackbird knows his song") foretell the tragicomic nature of his roller-coaster life. Touring the world's concert stages, Blair was a hit in New York, where newspapers called him a "credit to his dwindling race."

In Manhattan, he discovered his common cause with African Americans, but eventually, like Jack Johnson and Paul Robeson, the celebrated Aborigine was viewed as "uppity" by the dominant culture. Once he began to speak stridently for his people's cause, his singing career faltered and ended. Although reduced to running a gas station, the charismatic Blair remained a symbol of hope for Aborigines.

His children were criticized for being either too black or not black enough. In the 1970s, Harold's public voice was displaced by a more militant generation of young Aborigines, and he bowed out of the fray. Meanwhile, his marriage and family life were crumbling as he took a mistress. Fighting to keep up appearances, Harold and his wife and kids smiled bravely when Australian television's *This Is Your Life* made him a surprise subject in 1976. Two weeks later, at the age of fifty-two, Harold Blair was dead.

In *Byker,* by Amber Films, local musicians playing rickety pianos and scratchy fiddles entertain a blue-collar crowd in an English pub, even as the urban developer's wrecking ball hangs over the celebrants' heads. The slum dwellers of *Byker* come amazingly alive in this film, with their aspirations, tragedies, and impending displacement woven into a loving, wrenching story. A building half-demolished, the outer walls gone, stands in the late-evening shadows. Evocative montages of still photographs provide poignant, intimate glimpses into the lives of individuals, and these are juxtaposed with pompous government pronouncements of state housing policies and, above all, with the tenaciousness with which the Byker folk cling to the only hometown they have ever known—a doomed neighborhood whose worn, bleak streets hold cherished memories.

Among the festival's true delights is Katia Forbert Petersen's film, *God Gave Her a Mercedes-Benz.* In this Danish entry, we meet a tough matron known as Mama Benz, who conducts a voluminous textile business in Lome, Togo (West Africa). So successful is she that she rides around the hot, dusty town, where many go barefoot, in a spanking new, air-conditioned Mercedes. Practically illiterate, she can nevertheless hold in her head thousands of transactions in ten different currencies. Women work for her and are acknowledged to be the best at business. "Here, it's the reverse of other countries," says one. "The women chase money more than the men do."

The filmmaker lingers lovingly on Mama Benz's stock in trade, the warehouse full of colorful bolts of fabric with patterns named Democracy (portraits of Nelson Mandela), Baby in Belly (children's eyes looking through stylized keyholes), and Women's Rights (one bird in a cage with an open door and another bird flying out). But we soon get another glimpse of Mama Benz as she visits her farm in the country. Grabbing a machete, the venerable trader delivers a vicious backhand chop to a palmetto frond. Earlier, she gave a blow-by-blow description of how she had decked a mugger, which left the viewer pitying anyone who ticks this old lady off. This film begins as a view of an exotic place, with many unfamiliar sounds and colors, and ends by evoking hustlers and entrepreneurs everywhere, including my aunt, haggling at a bargain basement sale. ☐

From God Gave Her a Mercedes-Benz, *by Katia Forbert Petersen*

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This View of Life

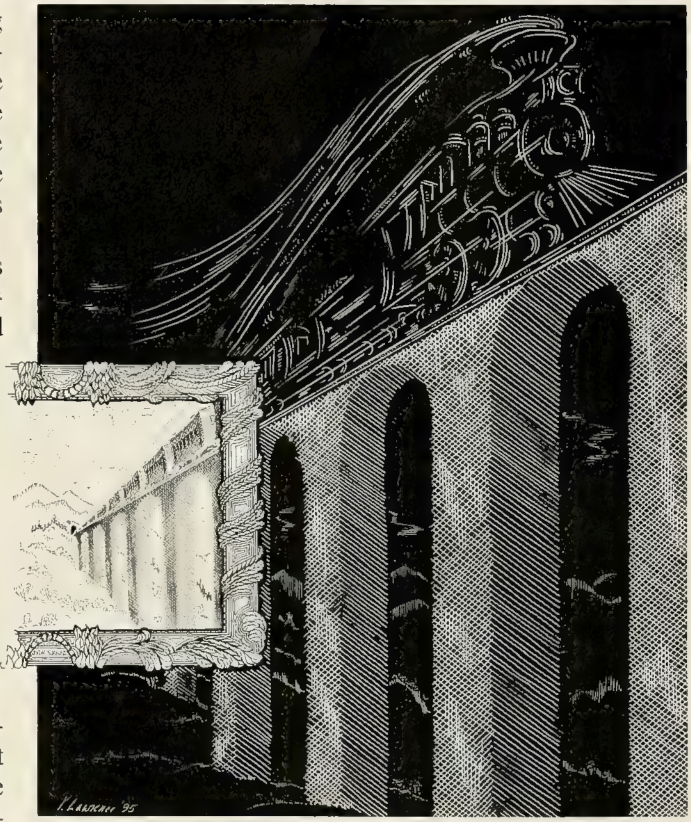
Continued from page 19

with a paddle wheel steamer shown prominently in a painting of Dover Castle in 1822 (passenger steamboats only started to operate between Calais and Dover in 1821) and culminating in a long series of paintings and drawings featuring steamboats on the Seine, done during the 1830s. A perceptive commentator, writing in the *Quarterly Review* in 1836, praised Turner for creating "a new object of admiration—a new instance of the beautiful—the upright and indomitable march of the self-impelling steam boat." He then specifically lauded "the admirable manner in which Turner, the most ideal of our landscape painters, has introduced the steam-boat in some views taken from the Seine."

This reviewer then credits Turner for his fruitful and reinforcing union of nature and technology:

> The tall black chimney, the black hull, and the long wreath of smoke left lying on the air, present, on his river, an image of life, and of majestic life, which appears only to have assumed its rightful position when seen amongst the simple and grand productions of nature.

The steam tug in *The Fighting* Temeraire is not spiteful or demonic. She does not mock her passive burden on the way to destruction. She is a little workaday boat doing her appointed job. If Turner's painting implies any villain, we must surely look to the bureaucrats of the British admiralty who allowed the great men-of-war to decay and then sold them for scrap.



Vint Lawrence

Which brings me to Isambard Kingdom Brunel, the engineer who goes with Turner in my second pairing. How many of you know his name? How many even recognized the words as identifying a person, rather than a tiny principality somehow never noticed in our atlas or stamp album. Yet one can make a good argument—certainly in symbolic terms for the enterprise he represented, if not in actuality for his personal influence—that Isambard Kingdom Brunel was the most important figure in the entire nineteenth-century history of Britain.

For Brunel was the greatest practical builder and engineer in British industrial history—and industry powered the Victorian world, often setting the course of politics as firmly as the routes of transportation. Brunel (1806–1859) built bridges, docks, and tunnels. He constructed a floating armored barge, and designed the large guns as well, for the attack on Kronstadt during the Crimean War. He built a complete, prefabricated hospital, shipped in sections to the Crimea in 1855.

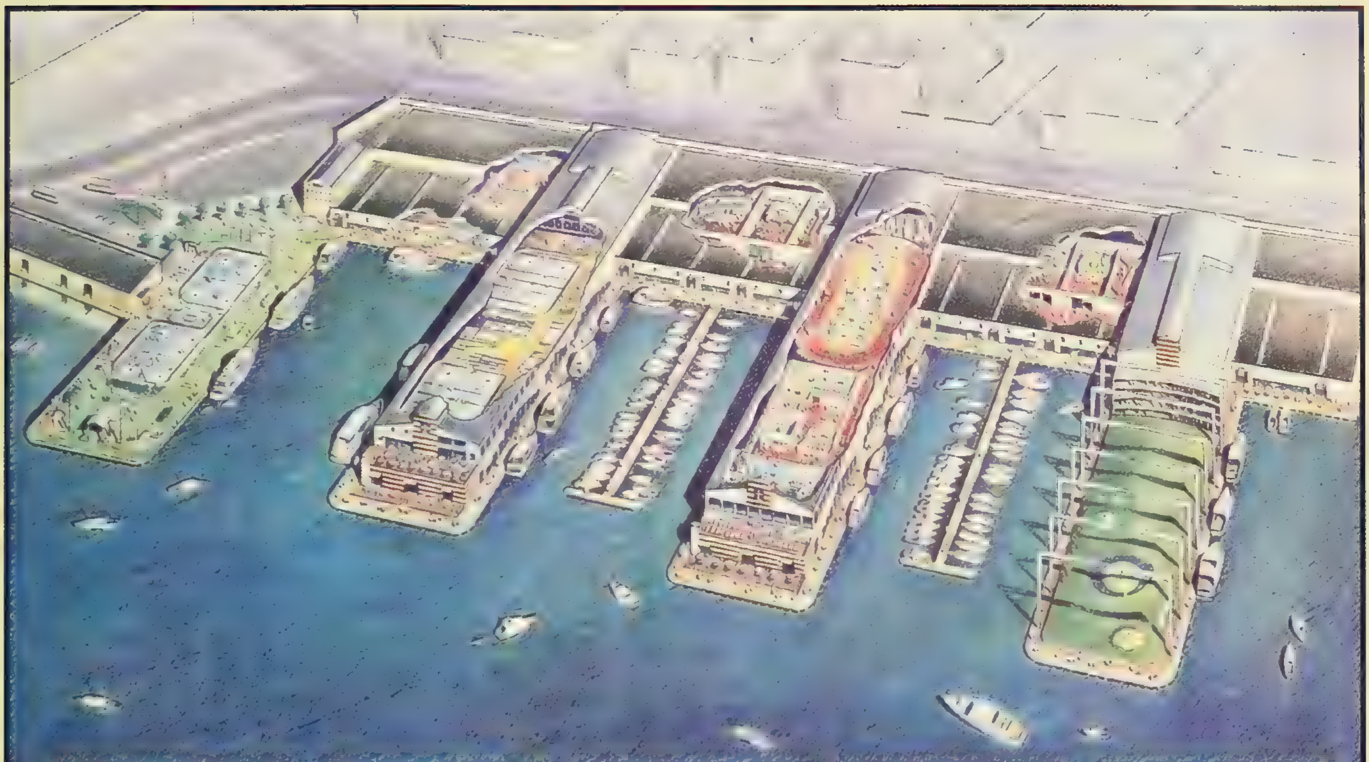
But Brunel achieved his greatest impact in the world of steam, both on land and at sea—and now we begin to grasp the tie to Turner. He constructed more than 1,000 miles of railroads in Great Britain and Ireland. He also built two railways in Italy and served as adviser for other lines in Australia and India.

For the culmination of his career, Brunel built the three greatest steam vessels of his age, each the world's largest at launching. His first, the *Great Western,* establishes the symbolic connection with Turner and *The Fighting* Temeraire. The *Great Western,* a wooden paddle vessel 236 feet in length and weighing 1,340 tons, was the first steamship to provide regular transatlantic service. She began her crossings in 1838, the year of the *Temeraire*'s last tow and demise. In fact, on August 17, 1838, the day after the sale of the *Temeraire,* the *Great Western* arrived in New York and the *Shipping and Mercantile Gazette* declared that "the whole of the mercantile world . . . will from this moment adopt the new conveyance." The little tug in Turner's painting did not doom or threaten the great sailing ships. Brunel's massive steam vessels signaled the inevitable end of exclusive sail as a principal and practical method of oceanic transport.

Brunel went on building bigger and better steamships. He launched the *Great Britain* in 1844, an iron-hulled ship 322 feet long, and the first large steam vessel powered by a screw propeller rather than side paddles. Finally, in 1859, Brunel launched the *Great Eastern,* with a double iron hull and propulsion by both screws and paddles. For forty years the *Great Eastern* remained the world's largest steamship. She never worked well as a passenger vessel but garnered her greatest fame by laying the first successful transatlantic cable. Brunel, unfortunately, did not live to see the *Great Eastern* depart on her first transoceanic voyage. He suffered a serious stroke on board the ship and died just a few days before the voyage.

Turner and Brunel are bound by tighter connections than the fortuitous link of the *Temeraire*'s demise with the inauguration of regular transoceanic service by the *Great Western* in the same year of 1838. Turner was also fascinated with steam in its other great manifestation on land—railroads. In 1844, in his seventieth year, Turner painted a canvas that many critics regard as his last great work: *Rain, Steam, and Speed—The Great Western Railway.* Brunel built this 200-mile line from London to Birmingham between 1834 and 1838 (and then used the same name for his first great steamship). Turner's painting shows a train, running on Brunel's wide seven-foot gauge, as the engine passes over the Maidenhead Railway Bridge (another famous construction, with the world's flattest brick arch), also designed and built by Brunel. The trains could achieve speeds in excess

AFTER A DAY WITH THE DINOSAURS, SPEND A DAY ON THE HUDSON



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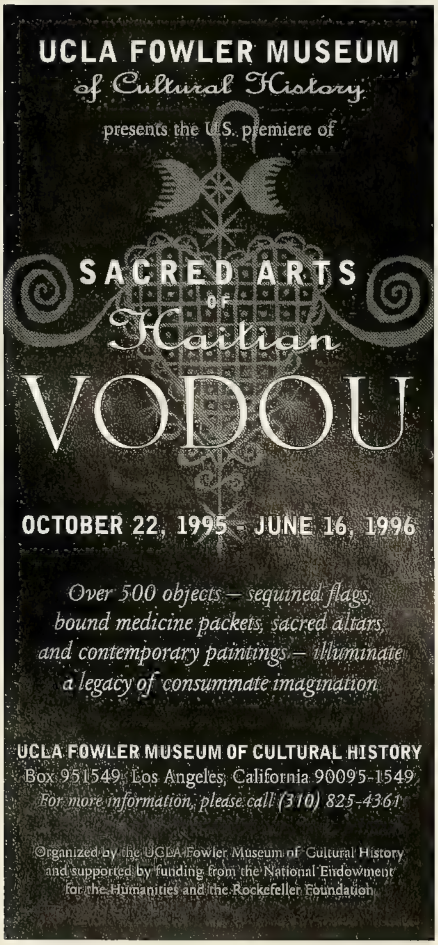

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of fifty miles per hour, but Turner has painted a hare running in front of the engine—and, although one can't be sure, the hare seems poised to outrun the train, not to be crushed under "the ringing grooves of change," to cite Tennyson's famous metaphor about progress, inspired by the poet's first view of a railroad.

We revere Turner, and rightly so. But why has the name of Isambard Kingdom Brunel, as inspired in engineering as Turner in painting, as influential in nineteenth-century history as any person in the arts, slipped so entirely from public memory. I do not know the full answer to this conundrum, but the myth of inexorability in discovery, ironically fostered by science as a source of putative prestige, has surely contributed by depicting scientists as interchangeable cogs in the wheel of technological progress—as people whose idiosyncracy and individual genius must be viewed as irrelevant to an inevitable sequence of advances.

Art and science are different enterprises, but the boundary between them is far more fluid and interdigitating, and the interactions far richer and more varied, than the usual stereotypes proclaim. As a reminder of both overlaps and differences, I recently read the first issue of *Scientific American*—for August 28, 1845—republished by the magazine to celebrate their 150th anniversary.

Scientific American was founded by Rufus Porter, a true American original in eccentric genius and entrepreneurial skill. Porter had spent most of his time as an itinerant mural painter, responsible for hundreds of charming and primitively painted landscape scenes on the interior walls of houses throughout New England. Yet he chose to start a journal devoted primarily to the practical side of science in engineering and manufacturing. In fact, the initiating issue features, as the main article, a story about the first landing in New York of "the greatest maratime [sic] curiosity ever seen in our harbour"—none other than Isambard Kingdom Brunel's second ship, the *Great Britain*. "This mammoth of the ocean," Porter writes, "has created much excitement here as well as in Europe. . . . During the first few days since her arrival at New York, she has been visited by about 12,000 people, who have paid 25 cents for the gratification."

If an artist could initiate a leading journal in science, and if Turner could greatly enhance his painted sunsets by using a new pigment, iodine scarlet, just invented by Humphry Davy of the Royal Institution, a leading scientific laboratory founded by Count Rumford in 1799, then why do we generally stress the differences and underplay the similarities between these two greatest expressions of human genius? Why do we pay primary attention to the artist's individuality, while constantly emphasizing the disembodied logic of science. Aren't these differences of focus mostly a matter of choice and convention, not only of evident necessity? The individuality of scientists bears respect and holds importance as well. I do accept that we would now know about evolution even if Darwin had never been born. But the discovery would then have been made by other people, perhaps in different lands, and surely with dissimilar interests and concerns—and these potential variations in style may be no less profound than the disparity between such artistic contemporaries as Verdi and Wagner.

I do not deny that the accumulative character of scientific change—the best justification for a notion of progress—establishes the major difference between art and science. I found a poignant reminder within a small item in the first issue of *Scientific American*. An advertisement for daguerreotypes on the last page includes the following come-on: "Likenesses of deceased persons taken in any part of the city and vicinity." I then remembered a book published a few years ago on daguerreotypes of dead children—often the only likeness that parents would retain of a lost child. (Daguerreotypes required long exposures, and young children could rarely be enticed to sit still for the requisite time—but the dead do not move, and daguerreotypists therefore maintained a thriving business, however ghoulish by modern standards, in images of the deceased, particularly of children.)

No example of scientific progress can be less subject to denial or more emotionally immediate than our ever increasing ability to prevent the death of young people. Even the most wealthy and privileged parents of Turner and Brunel's time expected to lose a high percentage of their children. As Brunel built his railways and Turner painted, Darwin's geology teacher, Adam Sedgwick, wrote to a friend about the achievements of his young protégé, then sailing around the world on the *Beagle* and therefore in constant medical danger, far from treatment in lands with unknown diseases: "[He] is doing admirable work in South America, and has already sent home a collection above all price. . . . There was some risk of his turning out an idle man, but his character will now be fixed, and if God spares his life he will have a great name among the naturalists of Europe." A concerned mentor would not need to fret so intensely today—a blessing from science to all of us.

I previously quoted the beginning of Colonel Calverly's recipe for a heavy dragoon, and will now close with the end:

> Beadle of Burlington—Richardson's show—
> Mr. Micawber and Madame Tussaud!

We know Mr. Micawber from *David Copperfield* and Mme. Tussaud for her wax statues. Richardson's show puzzled me until I found the following entry in my 1897 edition of *Chambers's Biographical Dictionary*: John Richardson, 1767–1837, "the 'penny showman' from Marlow work house who rose to become a well-to-do travelling manager." But who, or what, is the Beadle of Burlington?

I fell in love with Gilbert and Sullivan at age twelve and have therefore been wondering about those Beadles for forty years (not always actively, to be sure). Then, six months ago, and to my utter delight, I ran right into the Beadle of Burlington when no subject could have been further from my mind. I was walking down an early-nineteenth-century shopping arcade, just off Piccadilly in London, on my way to a meeting at the Royal Institution, where Humphry Davy had invented Turner's new pigment. Lord George Cavendish founded the Burlington Arcade in 1819 "for the gratification of the public" and "to give employment to industrious females" in the shops. Lord George established firm rules of conduct for people moving through the arcade—"no whistling, singing, hurrying, humming, or making merry." Such decent standards have to be enforced—and so they have been, ever since 1819, by a two-man private security force, the Beadles of Burlington. Traditions must be maintained of course, and the Beadles still wear their ancient garb of top hat, gloves, and coat with tails.

I looked at one of the Beadles in all his antiquated splendor, and I saw that he held both hands clasped behind his back. So I moseyed around to his other side (no hurrying) to find out what he might be holding—and I noted a cellular phone in his gloved hands. Technology and tradition. The old and elegant; the new and functional. *The Fighting* Temeraire and the steam tug. Art and science. The prophet Amos said, "Can two walk together, except they be agreed?" ☐

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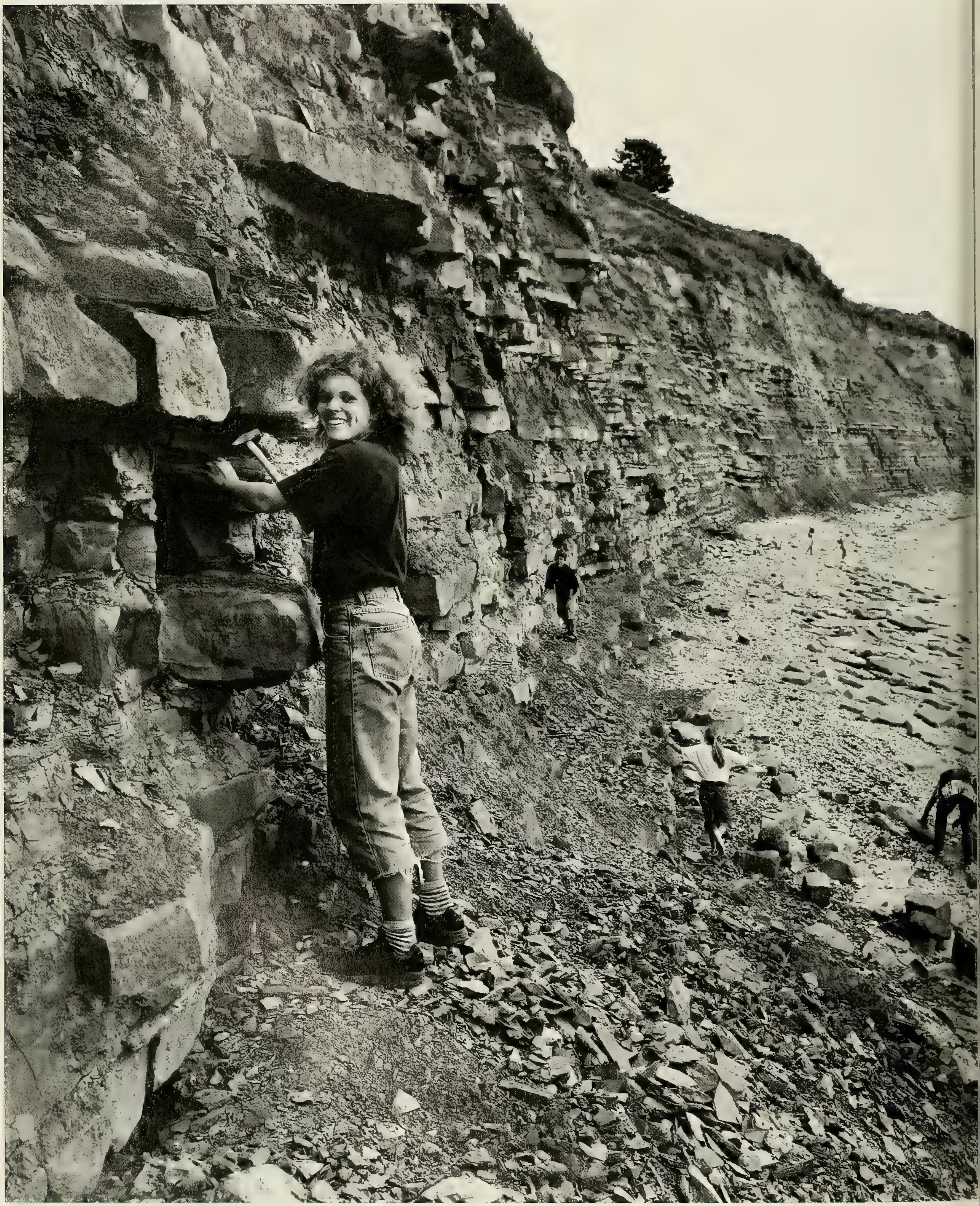

The steady erosion of Lyme's cliffs can pose a danger to fossil hunters. Hard hats are recommended.

Fossils by the Sea

by Michael A. Taylor
and Hugh S. Torrens

Photographs by Tim O'Sullivan

Lyme Regis, which sits above a wide, shallow bay on the English Channel coast, is a town popular today for its history and dramatic scenery. A long, curved sea wall, known as the Cobb, surrounds the harbor, which was a major port in the Middle Ages. Lyme became a fashionable holiday resort beginning in the late eighteenth century, and its steep, narrow streets are lined with Regency and Victorian houses. The town and its environs have been featured in literature from Jane Austen's *Persuasion* to John Fowles's *The French Lieutenant's Woman* (both Fowles's novel and the film are set in Lyme).

But the allure of Lyme Regis also lies much farther back in history. Some 200 million years ago, what is now southern Britain was near the equator, largely submerged under a subtropical sea. Animals that died in the warm waters or on the sea floor were often entombed and preserved in the gray, oozy mud of the bottom. Decades before the dinosaurs were recognized as a distinct group of animals, the finely preserved fossil marine reptiles of Lyme Regis and a few other areas in southwest England stimulated some of the earliest fossil vertebrate research in British science. The foremost collector of these Lyme fossils was a local Dorset woman, Mary Anning.

The geology of the region accounts for Lyme's abundance of fossils. The town is confined to a narrow patch of relatively stable ground bordered by cliffs. Rainwater percolates through the cliffs' clay and limestone—known as Lias rock, from an old quarrymen's term for layers—causing rocks to fall and mud to flow onto the beach. Expanses of naked Lias rock containing fossils are constantly being eroded to reveal the record of ancient marine life. In the eighteenth and nineteenth centuries, the influx of upper- and middle-class vacationers indulging in the new craze for sea bathing also provided a market for curios, and the townspeople of Lyme began to collect and sell the plentiful fossils.

One such collector was Richard Anning, a cabinetmaker of Lyme Regis. After his death in 1810, his wife, Molly, and children, Joseph and Mary, the latter born in 1799, carried on the family's fossil business. In 1811, Joseph found the head of a large "crocodile" on the shore in Lyme, and Mary found the rest of the skeleton a year later. This creature proved to be an ichthyosaur, a dolphinlike marine reptile. Although not the first ichthyosaur to be discovered, it became the type specimen of *Ichthyosaurus*—the scientifically described specimen for which the genus was officially named. This skeleton was no simple curio, and the Annings sold it to Henry Hoste Henley, the chief property owner in the area, for twenty-three pounds, the equivalent of several thousand pounds today. The head now rests in the Natural History Museum in London.

At times, the Annings were impoverished; at other times, going far beyond collecting to provide souvenirs for visitors, they made substantial sales to private collectors and museums, such as the Bristol Institution. Mary seems to have hunted for fossils almost daily, taking advantage of the tides and seasons in scouring the shoreline. Many of her best finds were made in winter, when erosion is most rapid. One of her letters ends with "the tide warns me I must leave off scribilling [*sic*]." Then, as today, high tide reached the foot of the cliffs, occasionally cutting off careless fossil seekers.

By 1824, Mary Anning was helping Professor William Buckland of Oxford to study coprolites—fossil droppings—by finding such fossils in association with well-preserved skeletons. The record of ancient marine life uncovered by Anning runs from coprolites and invertebrates, such as ammonites, to fishes and prize fossil reptiles, including several superb ichthyosaurs. In 1823, she discovered the first complete plesiosaur (a large, long-necked

Lyme Fossil Shop
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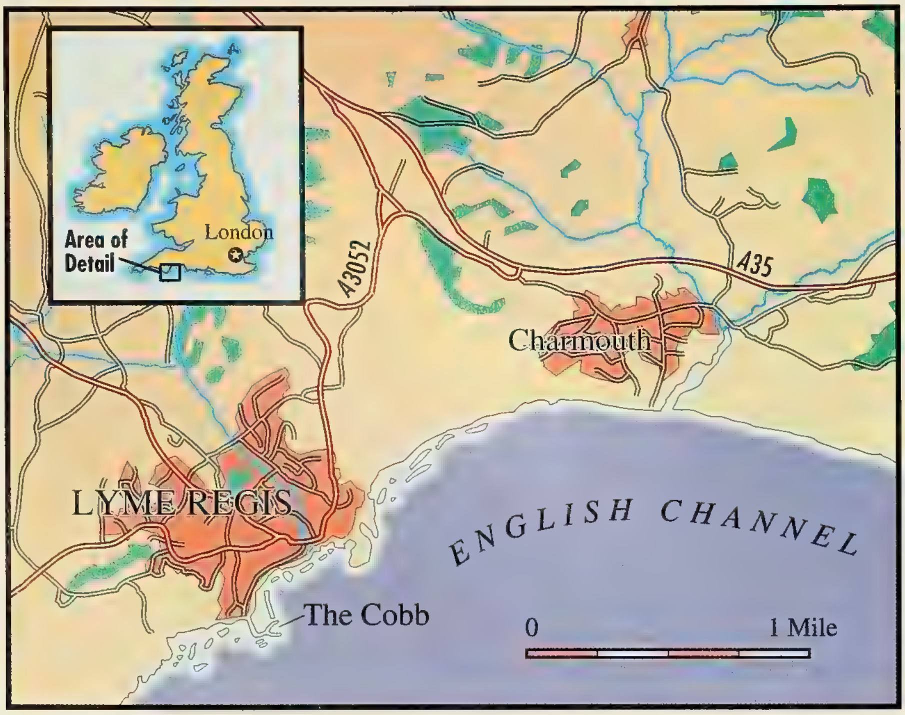
For the less adventurous, shops stock local fossils.

Patterns on a rock reveal a fossil ammonite in cross section.

marine carnivore); in 1828, the first British pterosaur (a flying reptile later named *Dimorphodon*); and in 1829 and 1830, two more complete plesiosaurs. These fossils enabled scientists to reconstruct an ancient marine ecosystem for the first time. In 1830, geologist Henry De la Beche drew a lively sketch entitled *Duria antiquior,* or "ancient Dorsetshire," showing the animals of the Lias rocks of Britain. The royalties of the sale of the first version went to Anning, who was then suffering a downturn in trade.

By this time, Anning herself had become a tourist attraction. Depending on their prejudices, visitors to Lyme recorded either a "prim, pedantic, vinegar looking, thin female; shrewd, and rather satirical in her conversation" or "a strong, energetic spinster . . . tanned and masculine in expression." She now corresponded with geologists all over England. Her letters, if somewhat idiosyncratic in their spelling and punctuation, are vivid documents still, often with fine sketches of the latest prime ichthyosaur cannily being offered. Phrases like "the most perfect yet discovered" abound. When, in 1832, she was hawking her find of the fossil chimera later named *Squaloraja* (after its mistaken identification as an intermediate between sharks and rays), she tempted Professor Sedgwick of Cambridge with comments such as "it is quite unique analogous to nothing" and "the only one in Europe price £50." Her assessment of this specimen stemmed from her discussion with J. S. Miller, curator of the Bristol Institution; at his suggestion, she had dissected a modern ray and confirmed the fossil's singularity.

When Anning died of breast cancer in 1847, the townspeople noted a drop in the number of visitors to Lyme. The geological community banded together to erect a stained-glass window in a local church in her honor. She was also awarded the unprecedented accolade—for a woman and nonmember—of an official obituary in the *Quarterly Journal of the Geological Society of London.*



Joe LeMonnier

Anning's contribution to paleontology is perhaps best exemplified by her 1823 discovery of a complete, nine-foot-long plesiosaur, a strange sea animal with a tiny head atop an inordinately long neck and four paddles for swimming. Some time earlier, while examining ichthyosaur fossils, Henry De la Beche and another geologist, the Reverend William Conybeare, had realized that various odd bones and a partial skeleton were not those of an ichthyosaur but could be placed together as belonging to a new creature, which they called *Plesiosaurus*. Because this new attribution was criticized, Conybeare was delighted when Anning found the first complete skeleton in 1823. It was soon sold to the Duke of Buckingham and turned over to Conybeare for study.

Conybeare's conclusions, published in the *Transactions of the Geological Society of London* in 1824, are fairly close to those of modern researchers (see box below). Unlike them, however, Conybeare believed that the plesiosaur's apparently extreme deviation from the normal reptilian body form was designed by a Creator to adapt it to aquatic life; to him, it was an exquisite example of the orderliness and diversity of divine creation.

The theory of evolution by natural selection was not put forth by Charles Darwin and Alfred Russel Wallace until some decades later, but Conybeare's view was also in total contrast to contemporary Lamarckian evolutionary thought, which was popular in France and in radical circles in Britain. Even Conybeare and De la Beche's name for the creature indicated how their worldview stemmed from the ancient concept of the Great Chain of Being, a static series of links from the simplest to the most complex organisms.

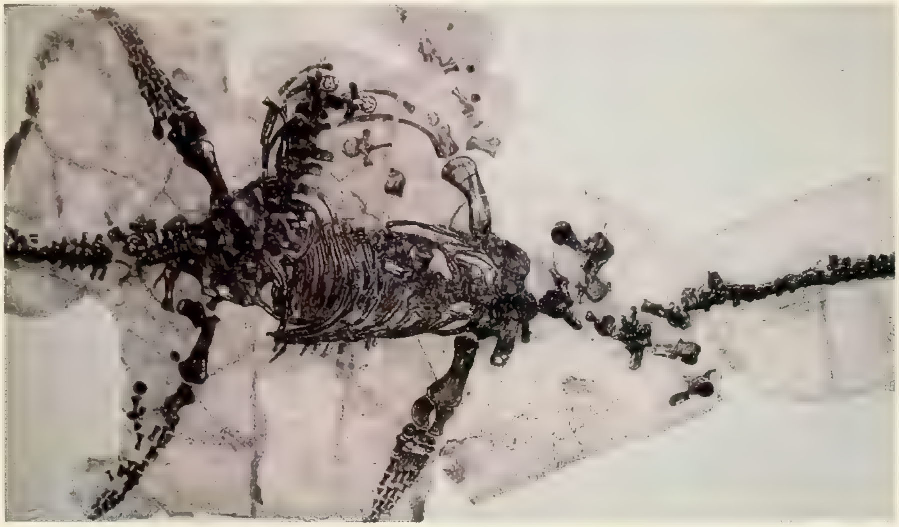
The Sea Monster of Dorset

In the winter of 1823, Mary Anning discovered the first complete skeleton of a strange sea creature that became known as *Plesiosaurus*. An apt description of the beast and its probable habits was written by geologist William Conybeare and published in the *Transactions of the Geological Society of London* in 1824:

> That it was aquatic is evident from the forms of the paddles; that it was marine is almost equally so, from the remains with which it is universally associated; that it may have occasionally visited the shore, the resemblance of its extremities to those of the turtle may lead us to conjecture; its motion, however, must have been very awkward on land; its long neck must have impeded its progress through the water; it may perhaps have lurked in shoal water along the coast, concealed along the sea-weed, and raising its nostrils to a level with the surface from a considerable depth, may have found a secure retreat from the assaults of dangerous enemies; while the length and flexibility of its neck may have compensated for the want of strength in its jaws and its incapacity for swift motion through the water, by the suddenness and agility of the attack which they enabled it to make on every animal fitted for its prey, which came within its extensive sweep.

Since Conybeare's day, plesiosaurs have been found all over the world in rocks laid down from some 215 to 65 million years ago, from the latest Triassic, through the Jurassic, into late Cretaceous times, making them roughly contemporaneous with the dinosaurs. Until recently, relatively little work had been done on these animals' way of life, but paleontologists are starting to revise Conybeare's vivid picture of plesiosaur natural history. While the size of plesiosaurs—some are more than forty feet long—suggests that they were too heavy to visit the land and dig nests in which to lay eggs, they may have given birth to live young on the shore or, like some ichthyosaurs, in the water. We are not yet sure of just how they hunted or why one group of plesiosaurs, the elasmosaurs, needed necks twenty feet long to catch the fish and squid-like cephalopods that were their main prey. However, we do know that the "dangerous enemies" of plesiosaurs at various times in their long history included not only large ichthyosaurs, marine crocodilians, and the huge, seagoing lizards known as mosasaurs but also their own kind. In addition to the long-necked plesiosaurs, a short-necked variety, known as pliosaurs, plied the Mesozoic seas. Pliosaurs had huge heads with stout teeth. The killer whales of their time, they preyed on fish, ichthyosaurs, and other plesiosaurs, which they shook and twisted into chunks small enough to swallow whole.

English sites such as Lyme Regis are still the most important sources of Triassic and Jurassic plesiosaurs. My colleagues David Brown, of Newcastle University, Arthur Cruickshank, of Leicestershire Museums, and Glenn W. Storrs, of the Cincinnati Museum of Natural History and the University of Bristol, and I are now working our way through the fossils of these animals to elucidate their varied adaptations and their evolutionary relationships. Plesiosaur evolution is turning out to be rich and complex. In our current research, we are not only looking at new discoveries but are also returning to old museum specimens. Glenn Storrs has gone all the way back to Anning's original plesiosaur skeleton of 1823, below, which has been recently refurbished and returned to display in the Natural History Museum in London.—*M. A. T.*



The Natural History Museum, London

They had accepted British Museum curator Charles Koenig's suggestion of the name *Ichthyosaurus* for the plesiosaur's dolphinlike contemporary to show its intermediate position between fishes and reptiles, such as crocodiles and lizards. Koenig gave it the name *ichthys sauros,* Greek for "fish lizard." Conybeare and De la Beche decided that their newly found creature fit best between ichthyosaurs and modern reptiles, so they named it *plesios sauros,* or "nearer to reptile."

The work of these geologists was among the earliest fossil vertebrate research in British science. Not until 1842 were the dinosaurs classified and named the Dinosauria, by anatomist Richard Owen. The damaged skeletons and iso-

Visitor's Guide To Lyme Regis

Lyme is as rewarding for the visitor today as it was in Anning's time. On the southern coast of Dorset, England, off A35, the main road between Southampton and the cathedral city of Exeter, Lyme is a small town crammed into a compact area of comparatively stable ground on the River Lim, with cliffs on either side. The medieval port is surrounded by the curved stone Cobb, famous as the site of Louisa Musgrove's fall in Jane Austen's *Persuasion.* A walk out to the end of this sea wall gives a stunning view of the town and its surrounding cliffs. The town's Victorian atmosphere has been preserved not only through the buildings but also on film, as the setting for *The French Lieutenant's Woman.*

Getting around in Lyme is fairly easy. You can walk everywhere, that is, if you don't mind walking uphill. The newly restored Lyme Regis Museum, with its fossils, paintings, local lace, and other historical items, is built on the spectacular seafront site of the Anning family's first fossil shop. Nearby, at the mainly fifteenth-century parish church, you can find Mary Anning's grave and her memorial stained-glass window. Also, the site of the converted nonconformist chapel where the Annings once worshiped is now home to Dinosaurland, a privately owned fossil museum.

Fossils can be found near both Lyme and Charmouth, which lies some two miles east of Lyme on the English Channel. Charmouth is perhaps the best place to begin fossil hunting. The Charmouth Heritage Coast Centre's Ranger Service offers guided collecting tours of the fossil-bearing rocks on the shore, as do several Lyme Regis fossil shops, which carry on Anning's tradition with a fascinating range of stock. You can also explore the dramatic coast around Lyme and Charmouth for yourself; be forewarned, however, that owing to the instability of the cliffs, the coast is constantly changing, making it possible for the unwary to become lost in the rough terrain or trapped by the tide.

Throughout winter, storms expose fossils, and the area is filled with professional fossil hunters scouring the cliffs. For tourists, late spring, summer, and early fall are the best times to visit Lyme Regis. Small fossils are abundant, and the museum and other attractions are sure to be open. For more information about visiting Lyme, call the Tourist Information Center (44-1297-442138).

Readers can find out more about the town in John Fowles's *A Short History of Lyme Regis* (Boston: Little, Brown & Co., 1983). In Lyme, a variety of maps, pamphlets, and books about the town and its environs are available. The geologically minded will find information about the local scene in the Geologists' Association Guides No. 22, *Geology of the Dorset Coast,* by Michael House, and No. 47, *The Coastal Landforms of West Dorset,* by Robert J. Allison.—*M. A. T.* and *H. S. T.*

Lyme Regis, England

The Cobb, a stone sea wall, curves around the old harbor.

lated bones with which Owen had to work were a far cry from the marine reptiles' exquisite skeletons. As a result, much of the early popular interest in fossils was stimulated by these extinct marine reptiles. In his poem "In Memoriam," Alfred, Lord Tennyson, commented upon these discoveries (*see* "Red in Tooth and Claw," by Stephen Jay Gould, *Natural History,* November 1992). In the 1850s, when the life-sized models of extinct reptiles and other fossil animals by sculptor Benjamin Waterhouse Hawkins were unveiled at the Crystal Palace recreation park in south London, the marine reptiles considerably outnumbered the dinosaurs.

As time passed, history began to have its own view of Mary Anning. It strangely concentrated on her childhood discoveries. Our favorite example is from the 1925 edition of the *Children's Encyclopaedia,* by Arthur Mee, a book on which whole generations of British schoolchildren were brought up. (The United States edition was called *The Book of Knowledge.*)

The book depicts a twelve-year-old Mary Anning with the skull of the "first ichthyosaurus found in England." Anning's age is correct, but it was her brother Joseph who found the skull—not the first—in 1811, embedded in fallen rock, rather than nicely exposed as in the scene. More importantly, this view of Anning as childlike persisted even after the research, in the 1930s, of W. D. Lang—formerly of the Natural History Museum, London—revealed the facts of Anning's story. She continued to be largely depicted as a little girl in a pinafore, rather than a hard-working, independent, and knowledgeable collector. It is time her adult achievements are properly acknowledged.

Almost certainly the grown-up Anning was written out of history in part because she earned her living as a fossil collector and was thus "in trade." In the England of her day, a scientific pursuit such as fossil collecting could be a way of gaining social acceptance only if one was a gentleman or a lady with an independent income, or if one collected fossils as a pastime, not for a living. The wealthy who bought Anning's fossils ("collectors" by virtue of money) were credited as the donors to museums, their names were noted on labels and in the formal scholarly monographs about the specimens, and some even had new fossils named after them. Not until 1878 was a British fossil named after Anning—a coral, *Tricycloseris anningi*—and to this day, no British fossil reptile is named after her. In the five most important institutions to take Lyme fossils in Anning's day, only one specimen, a coprolite in Oxford's University Museum, is directly recorded as having been donated by her. But this silence hides the unrecorded purchases of hundreds of Anning specimens. The late David Price, of the Sedgwick Museum in Cambridge, discovered from Anning's own correspondence and sketches that several of the prize ichthyosaurs in that museum were originally collected by her.

An unmarried, provincial, working-class woman, Anning earned her living from her eye for fossils but failed to achieve lasting recognition from English society. After 1885, her private papers were dispersed as the mementos of a woman who was a "curiosity." Today, historians of science are rediscovering the Anning family's contribution and reevaluating Mary Anning's role as a woman of crucial importance in the history of vertebrate paleontology. □

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Turner's Hall Woods, Barbados

by Robert H. Mohlenbrock

The easternmost island of the Caribbean, Barbados emerged from beneath the sea some 750,000 years ago. Formed when layers of sedimentary rock were scraped off a subducting tectonic plate and uplifted, it differs geologically from the volcanic islands of the Lesser Antilles, one hundred miles to the west. This sedimentary rock is visible in the hilly northeast of Barbados. Elsewhere on the island it is overlain with a mantle of coral limestone, up to 300 feet thick, deposited when the land still lay beneath the sea. Twenty-one miles long, north to south, and nowhere more than fifteen miles wide, Barbados offers sandy beaches on both its windward Atlantic seacoast, with its rocky cliffs, and its more placid and less rugged-looking leeward side.

Barbados was inhabited in prehistoric times by people who grew manioc and other crops near their settlements, which were primarily along the coast. The island was apparently depopulated in the early 1500s, however, as Spanish and Portuguese slavers raided the southern Caribbean and the people of Barbados were captured or fled elsewhere. The first English settlers, who arrived on the island in 1627, described it as uninhabited and heavily forested. By 1665 the original forest cover was almost all cleared to make way for crops of tobacco and sugarcane, and pastures and fields of sugarcane dominate the landscape today. Only one forty-six-acre tract of forest remains that has never been cleared—and presumably exemplifies the presettlement conditions. Known as Turner's Hall Woods, it occupies the slopes of a gully about a mile north of 1,104-foot-high Mount Hillaby, the island's highest point.

You need a guide to show you the way to Turner's Hall Woods because its location is not marked, and most people in Barbados have no idea where it is. After driving to the site, you walk along an abandoned road for a few hundred feet down to an old wooden bridge that crosses a creek. To the right, or east, downstream from the bridge, the creek passes through a gully that is about one-half mile long and up to 1,200 feet wide. Turner's Hall Woods covers the steep slopes of this gully. No trails lead through the thick vegetation, but with patience you can pick your way into the woods. Although passage is difficult at times, at least it is not dangerous, since there are no poisonous reptiles on the island.

Turner's Hall Woods, left, lives on as a reminder of the forested landscape of prehistoric Barbados. Above: Pastures and young trees cloak the nearby hills.

All photographs by Ronnie Carrington

Barbados has a lengthy dry season from January to May, so Turner's Hall Woods is not a typical tropical rain forest laden with epiphytes and lianas. It contains both evergreen trees and trees that briefly shed their leaves (these are known as semideciduous trees). There are several distinct layers of vegetation, with the tallest trees towering as much as 120 feet high. The most conspicuous of these is a cabbage palm, one of the royal palms. This evergreen's crown of large leaves spreads gracefully from the top of a hard, gray trunk that is ringed by scar marks left by earlier leaves.

Joining the cabbage palm in the upper tier of the forest are four semideciduous species. The largest of these is the silk cotton tree, which has a very dense trunk. When I finally made my way through the thick woods to the silk cotton trees, I found one with a trunk diameter of nearly eight feet. Silk cotton trees usually bear large pink flowers every other year. Some, however, flower on one side one year and on the other side the following year.

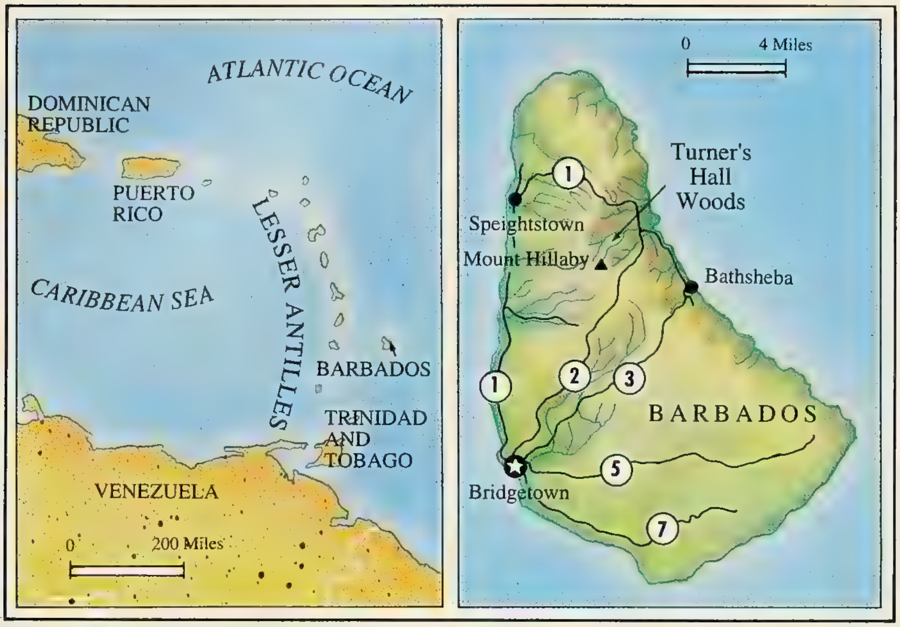
Another huge tree in the uppermost canopy is *Hymenaea courbaril,* known in Barbados as the tropical locust tree. Turner's Hall Woods contain some that are more than a hundred feet tall, with trunk diameters of about four feet. Stands of these trees, once common elsewhere in Barbados, were long ago cut down for their wood, highly valued for making furniture, cabinets, and other products.

The wood of a third species, fiddlewood, was once used in making musical instruments. This tall tree is a member of the verbena family.

Also in the upper canopy is the sandbox tree, a member of the spurge family. Its woody fruit, shaped like a large peeled tangerine with ribs all around, explodes with a loud pop when ripe, catapulting seeds and sharply pointed shell fragments up to two hundred feet away. As an additional hazard, the seeds are poisonous to many animals, including humans. Florida botanist Mary Barrett has called the sandbox tree a very dangerous tree, one that stabs, poisons, and shoots.

Beneath the upper canopy in Turner's Hall Woods is a dense layer of trees with

Joe LeMonnier



Turner's Hall Woods

For visitor information write:
Barbados Authority of Tourism
Harbour Road, P.O. Box 242
Bridgetown, Barbados
(809) 427-2623

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an average height of forty to sixty-five feet. One is the jack-in-the-box tree, whose family, the Hernandiaceae, has no representative in the United States. The common name refers to the fruits, which are spherical, bladdery yellow cups, each containing a single black seed. On a windy day, the wind whistles as it blows through the cups. A small stand of these evergreen trees lies high up on the south side of the gully, along with Spanish oaks, fustic trees, and wild clammy cherry trees.

Spanish oak in Barbados is not an oak at all but a leathery-leaved member of the legume family. Fustic, whose leaves hang downward as if wilted, has a yellow wood that is the source of a natural pigment used to dye fabrics. And wild clammy cherry, although not related to cherries, nonetheless has red, cherrylike fruits. Its upper branches provide a home in Turner's Hall Woods for dozens of epiphytic orchids known as eyelash orchids because of their fringed white petals.

Another layer of trees consists of plants that range in height from twenty to forty feet. The wild coffee trees' white flowers resemble those of plantation coffee trees but they do not produce coffee beans. The candlewood tree has velvety, triangular fruits. And the leather coat tree with its thick leaves is related to the sea grape, so common along seashores. Its circular leaves, up to nineteen inches in diameter, are patterned with deep, sunken veins. Somewhat shorter than these trees is the macaw palm, whose fifteen-foot-tall trunk is densely covered with black, needlelike spines.

Clinging to the sides of many of the trees is a plant known as monkeytail, an *Anthurium* with leaves eighteen inches long and four inches wide. Its jack-in-the-pulpit-type blossom consists of a central spike, known as the spadix, surrounded by a leaflike growth, known as the spathe. Unlike the florist's *Anthurium*, which has a heart-shaped red spathe and a white spadix at its center, monkeytail has a green spathe with a purple spadix.

Among the obstacles to hiking through the forest are pinguin plants, members of the pineapple family that grow in dense thickets. Reaching nearly ten feet tall, pinguins have stiff, spiny-edged leaves that can rip into unprotected skin. There is also a species of dumb cane (*Dieffenbachia*) that is about three feet high and grows with stems so close together that getting through them is nearly impossible.

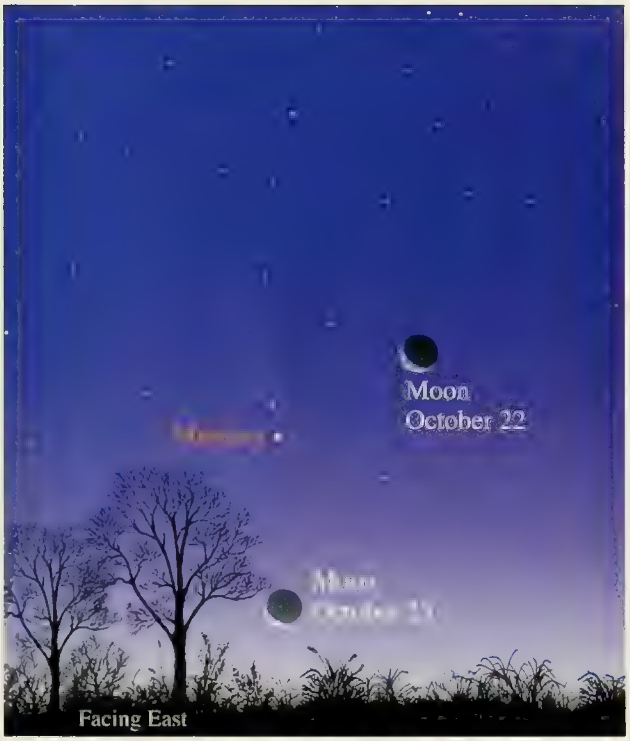
Turner's Hall Woods, which used to be in private hands, was preserved partly because the steep site made clearing vegetation difficult, and partly because of the wishes of its owners. Now the site belongs to the government. As long as these woods are protected, visitors will be afforded a glimpse of the island's past.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the U. S. national forests and other parklands.

An abandoned bridge lies near the entrance of the woods, which cover the steep sides of a gully.

Mercury Ascendant

by Joe Rao



In the predawn skies of late October, a crescent moon joins Mercury, which makes a rare nighttime appearance.
Dennis Davidson

Mercury is often referred to as "the elusive planet" because its orbit is so close to the sun that it is difficult to see. In *The Solar System and Back,* Isaac Asimov pointed out that "Mercury is hardly ever visible when it is truly dark. . . . I suspect, in fact, that many people today (when the horizon is generally much dirtier and the sky hazier with the glare of artificial light than it was in centuries past) have never seen Mercury." If you are among those who have never seen the innermost planet, you may get a chance between mid-October and early November, when Mercury will rise higher in the sky than usual, making it easier to spot.

On October 4, Mercury will be at inferior conjunction, passing almost directly between the earth and the sun. By the 13th, however, Mercury will move out of the sun's glare, and you can start looking for it about three-quarters of an hour before sunrise, close to the horizon, just south of due east. As it moves rapidly away from the sun during the following weeks, the yellowish planet triples in brightness. From the 17th to the 23d, Mercury will rise just prior to the onset of morning twilight—in other words, in a totally dark sky.

On October 20 Mercury attains greatest elongation, a little more than 18° west of the sun, as seen from midnorthern latitudes. After the 20th, Mercury begins a more leisurely slide back toward the sun. Although it enters the bright morning twilight by month's end, the planet may remain visible until November 8. On that date, it will be rising forty-five minutes before sunup and shining at magnitude –1.0. Thus, for nearly four weeks, the "elusive" planet will be easy to spot.

The Planets in October

On the 22d, a thin crescent moon lies 6° to the right of **Mercury**. On the 23d, the moon (now less than twenty hours from new phase) will appear as a narrow arc of light hovering just above the east–southeast horizon, 9° below Mercury. On the morning of the 30th, look for Mercury 4° above and to the left of the bluish star Spica. Mercury will appear five times brighter than the star.

Venus returns to the evening sky toward the end of October, when you might glimpse the planet shining brilliantly at magnitude –3.9 low in the west–southwest.

Mars sets about one and a half hours after sundown through most of October. By month's end, this yellowish orange planet will be 4° to the north of its "rival," the ruddy star Antares. On the evening of the 26th you'll find Mars 7° below and to the west (right) of the moon.

Jupiter is this month's brightest evening "star" until it relinquishes the title to Venus toward month's end. On the 1st, Jupiter sets one and a half hours after twilight ends; by Halloween it sets only about a half hour after darkness falls. On the 26th, it will be to the left of the crescent moon and above and to the left of much dimmer Mars.

Saturn is well up in the southeast at sunset. Highest in the south in late evening, it sets a few hours before sunrise. Saturn's rings appear to thicken slightly as they tilt toward the sun—enjoy them while you can because next month they will again be plunged into darkness.

The **Moon** is at first-quarter phase on the 1st at 10:36 A.M., EDT; October's full moon, also known as the hunter's moon, occurs on the 8th at 11:52 A.M., EDT; last quarter is on the 16th at 12:26 P.M., EDT; new phase is on the 24th at 12:36 A.M., EDT; and first quarter occurs again on the 30th at 4:17 P.M., EST.

Two eclipses take place this month. The first, on the 8th, is a penumbral eclipse of the full moon that will be visible only in Asia. Asia will also be treated to a total eclipse of the sun on the 24th. The path of totality, averaging thirty-eight miles wide, will start at sunrise over Iran, only fifteen miles north of the holy city of Qom, then move south and east across Afghanistan, Pakistan, and northern India to Indochina, Borneo, Celebes, and the Moluccas. Maximum duration of totality is 2 minutes 9.6 seconds.

October Meteors—One of the most notable and dependable of the annual displays of "shooting stars" are the Orionid meteors, which peak during the morning hours of the 22d. Look for them overhead and to the southeast; you can expect to average a meteor sighting every three or four minutes, radiating from a spot near the bright red star Betelgeuse, in Orion.

Daylight saving time ends on October 29 for most parts of the country. Clocks should be moved back one hour. Officially, you are supposed to do it at 2:00 A.M. local daylight time.

Meteorologist Joe Rao is a lecturer at the American Museum-Hayden Planetarium.

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Recommended travel and reading from the authors of this month's features

Drum playing, a central component of Vodun ceremonies, is a means to bring on trances.
Henning Christoph; Das Fotoarchiv

Etosha National Park, Namibia

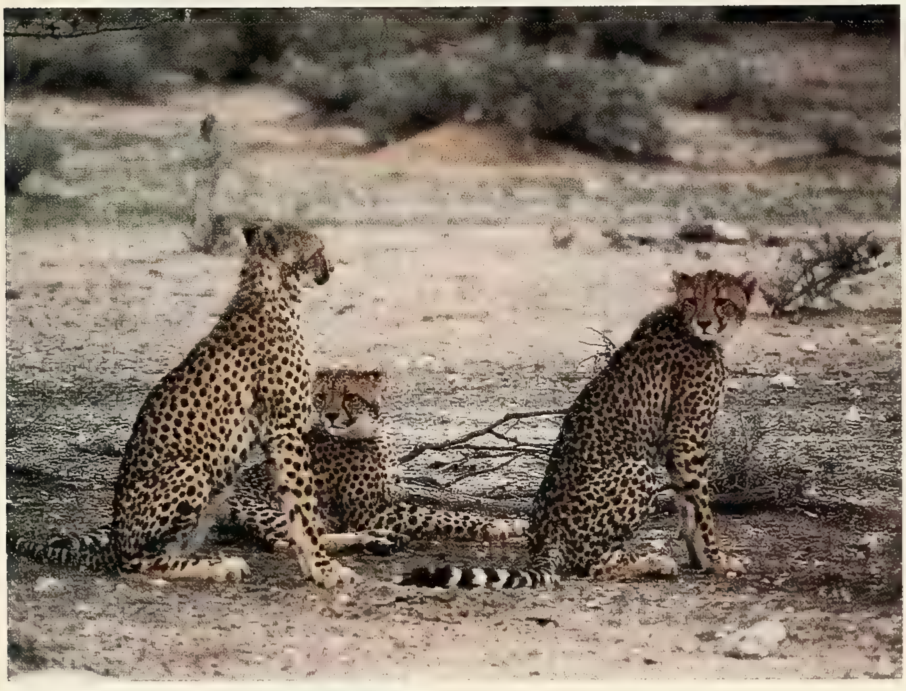
(Story on page 50)

Etosha National Park in northern Namibia needs little introduction to wildlife enthusiasts. Covering 5 million acres, it is one of the world's largest parks and hosts a variety of animals, including comparatively large populations of endangered species typical of the arid savanna of southern Africa: black rhinoceros, black-faced impala, roan antelope, Hartmann's mountain zebra, and the Damara dik-dik. Many carnivores (including lions, cheetahs, leopards, and spotted and brown hyenas), more than 320 bird species, and the largest elephants in Africa can also be found in Etosha.

From Windhoek, Namibia's capital and site of the international airport, rental cars are available for the 300-mile drive to Etosha over well-maintained roads. Rental car is also the best way to get around the 420-mile network of gravel roads that traverse the park.

Three fenced, year-round rest areas offering a variety of accommodations, from luxury chalets to camping, are located along the southern border of the Etosha Pan, a usually dry saltwater basin that lies near the center of the park. At Okaukuejo, the westernmost camp, a watering hole lit up at night enables visitors to catch sight of rarely seen nocturnal creatures. Reservations for all accommodations at Etosha can be made through Central Reservations: Resorts—Ministry of Environment and Tourism, Windhoek, Namibia (telephone 264-61-236975).

Willie and Sandra Olivier's *Visitors Guide to Namibia* (Johannesburg: Southern Book Publishers, 1989) offers an overall view of many of the country's natural sites, including Etosha National Park, the Namib Desert, Skeleton Coast National Park, and others. To find out more about large lizards, read Robert Sprackland, Jr.'s popular book, *Giant Lizards* (Neptune, NJ: TFH Publications, 1992).



Cheetah cubs in Etosha National Park
John A. Phillips

The Gulf of California

(Story on page 32)

For viewing the sea life in the Gulf of California (also known as the Sea of Cortez), La Paz, Mexico, with its many hotels and easy accessibility, is one of the best places to start. From La Paz, excursions to the Espiritu Santo seamount (known locally as El Bajo) and other sites can be arranged through several local tour companies.

Among the large variety of fish, marine mammals, and marine invertebrates found in the Gulf of California are whale sharks, manta rays, tuna, marlin, schools of jacks, colorful reef fish, whales, sea lions, sponges, and coral. Some of the more popular underwater activities in this area include swimming with the playful sea lion pups of Los Islotes, a sea lion rookery; snorkeling among coral reefs; and exploring the sunken wreck of the 300-foot-long ferry *Salvatierra*.

Each year in March and April, blue whales migrate to the Gulf of California. Whale watchers can also see humpback, sperm, minke, gray, and killer whales, as well as schools of dolphins. For birders, frigate birds, blue- and brown-footed boobies, terns, blue herons, egrets, ibises, and storm petrels abound in the area.

Scuba diving is one of the best ways to explore the Gulf of California. Author Peter Klimley, however, prefers free diving for looking at hammerhead sharks, finding that bubbles from the scuba tank may frighten the sharks away. The best time to see hammerheads is from late May to the end of October, but the La Paz diving season continues through December.

Many of the hotels in La Paz offer packages that include sea trips ranging from snorkeling and scuba diving to whale watching and kayaking. There are also packages available for those who prefer life aboard ship. Guided tours are regularly available in La Paz.

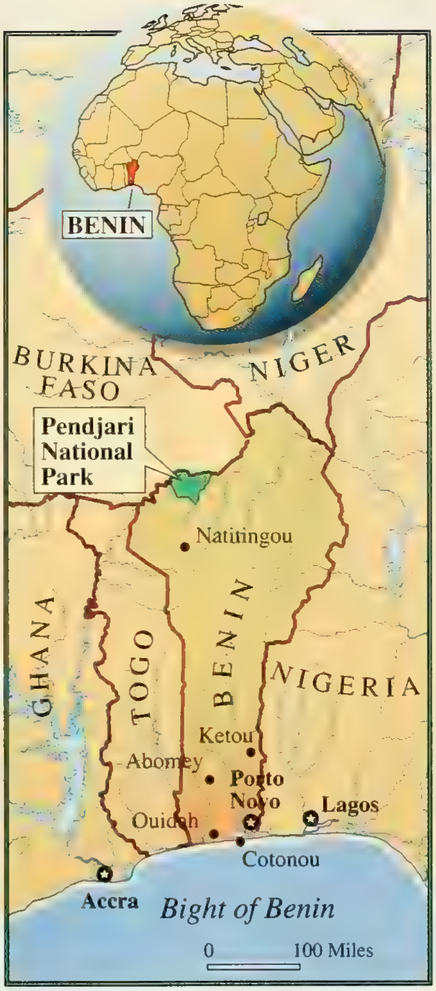
Those wanting more information on sharks can read Richard Ellis's *The Book of Sharks* (San Diego: Harcourt, Brace Jovanovich, Inc., 1983).

Vodun: Benin

(Story on page 40)

Benin's nominal capital is Porto Novo, but Cotonou, the political and financial center of the country located nearby on the coast of the Bight of Benin, boasts all the amenities, including comfortable hotels and the international airport. Rental cars and buses are also available in Cotonou.

Various sites throughout the southern half of the country offer insight into Benin's cultural history. In Porto Novo, Ketou, and Abomey, visit the restored palaces of the ancient kings of the Gun, Yoruba, and Fon, just three of the forty-two indigenous ethnic groups that make up 99 percent of Benin's population. In Ouidah, the ancient slave port, visitors can tour a historical museum, the Vodun Python Temple, old Portuguese and French forts, and public monuments linked to the country's early history.



Joe LeMonnier

When traveling to the north, plan to visit the two-story earthen "castles" of the Somba ethnic group in the area around Natitingou. At Pendjari, a 630,000-acre animal park in the northwest, you can see elephants, lions, hippopotamuses, crocodiles, boar, and large antelopes, all in their traditional savanna setting.

Festivals linked to Vodun rites can be seen in many towns of southern Benin, especially from December to March.

For more information about Vodun, read Suzanne Blier's *African Vodun: Art, Psychology and Power* (Chicago: University of Chicago Press, 1995). Karen McCarthy Brown's *Mama Lola: A Vodoo Princess in Brooklyn* (Berkeley: University of California Press, 1991) is a good source on the ethnography of Benin.

Margaret Mead Film Festival: American Museum of Natural History

(Story on page 56)

The Margaret Mead Film and Video Festival, the largest ethnographic/documentary festival in the United States, will be held at the American Museum of Natural History from October 18 to October 23. Named for the celebrated anthropologist who was associated with the Museum for more than fifty years, the festival is devoted to realizing her goal of extending available cross-cultural information to general audiences. Simultaneous screenings will be held in the Museum's four theaters over the six-day period, and fifty-eight films are scheduled for projection. (Fifteen of the movies are reviewed in this issue.) Informal discussions with some of the directors and anthropologists involved in the making of the films are also scheduled to take place following many of the viewings.

A number of this year's films offer a look at the varieties of religious expression worldwide. *Mundo Milagroso* explores the impact of religious apparitions on a Mexican-American community; *The Trials of Telo Rinpoche* tells of a young man born in Philadelphia to Indian immigrants and confirmed by the Dalai Lama as a reincarnated lama; a religious pilgrimage in Cuba is documented in *La Promesa*; and *Holy Madness* explores the peculiar phenomenon of pilgrims to Israel overcome by religious zeal.

Other highlights from the festival include: *State of Weightlessness*, a Russian film that provides rare insight into the Soviet/Russian space program and contains some stunning footage of the moon; *The Vegetable Mob*, a look at first-generation Sicilian immigrants in suburban Australia who carry on the tradition, begun by their rural forefathers, of cultivating the superior tomato; and *Harlem Diary*, a film that defies media stereotypes and weaves a tale of hope and resilience in Harlem.

A portion of the Margaret Mead Film and Video Festival will tour the United States. For information about the film festival and informal discussion schedule, obtaining tickets, and the tour schedule, contact the Margaret Mead Festival office at (212) 769-5305.

Diary of a Museum Naturalist

A diary kept by Edmund Heller, a naturalist and explorer who first made a name for himself on the Smithsonian-Roosevelt East Africa Expedition of 1909–10, was recently donated to the Special Collections of the Library by collectors Jean S. and Frederic A. Scharf. Heller was hired by Roy Chapman Andrews, the Museum's legendary explorer, to gather specimens on the First Asiatic Zoological Expedition, 1916–17. During their year in the field, mainly in China's Yunnan Province, the expedition party ranged 2,000 miles on horseback, camping out and traveling at altitudes of 1,500 to 15,000 feet. About 3,000 specimens were collected, including 2,000 mammals, 800 birds, and 200 reptiles. (A full description of the expedition can be found in the December 1917 issue of the *American Museum Journal, Natural History*'s original name.)

After the expedition, Heller spent nearly three months traveling alone through northern China. The recently donated diary contains his day-by-day impressions of Peking (as shown in the excerpt below) providing a vivid firsthand account of the imperial city in 1917.

October 19

At 10 A.M., we started from the Wagon-Lits Hotel with a Cook's guide in rickshaws. . . . The way led along wide streets, 60 feet wide. . . . From the summit of the hill at the pagoda base (near the Winter Palace), Peking spreads out in all directions, but the traveler is bewildered to find that only a vast forest of trees is spread out before him with an occasional pagoda or gate looming up amid the green. . . . The forest trees on the hill were chiefly juniper, with yellow pine, a peculiar variety of white barked pine, ash (acacia) trees and willows about all the lakes and streams.

October 21

The horse market, situated in a field near the Temple of Heaven, is interesting. Here are to be seen many Mongolian ponies for sale, being led about a large ring, saddled and ready to ride. The purchaser rides, or has somebody ride the pony on a straight away course following the Wall. The gait is always a fast, even trot, or single foot, which gives the rider a steady seat. . . . Automobiles are not common, as there are no roads outside the city where they can travel. Camel caravans are quite often seen . . . great large brutes of the Bactrian type, bearing two high humps between which the saddle is securely placed.

October 22

In one [fur] shop I saw a fine Manchurian tiger skin with long hair for $200. This [had] a tawny ground, which is the rule in Manchurian tigers. This shop also had three fine orange-colored tiger skins of the usual short haired sort, and these were cheaper at $150 to $100. . . . I saw no panda or flying squirrel skins in any of the shops, the skins here all coming from Mongolia or Manchuria and none

Yunnan Province, First Asiatic Zoological Expedition, 1916.

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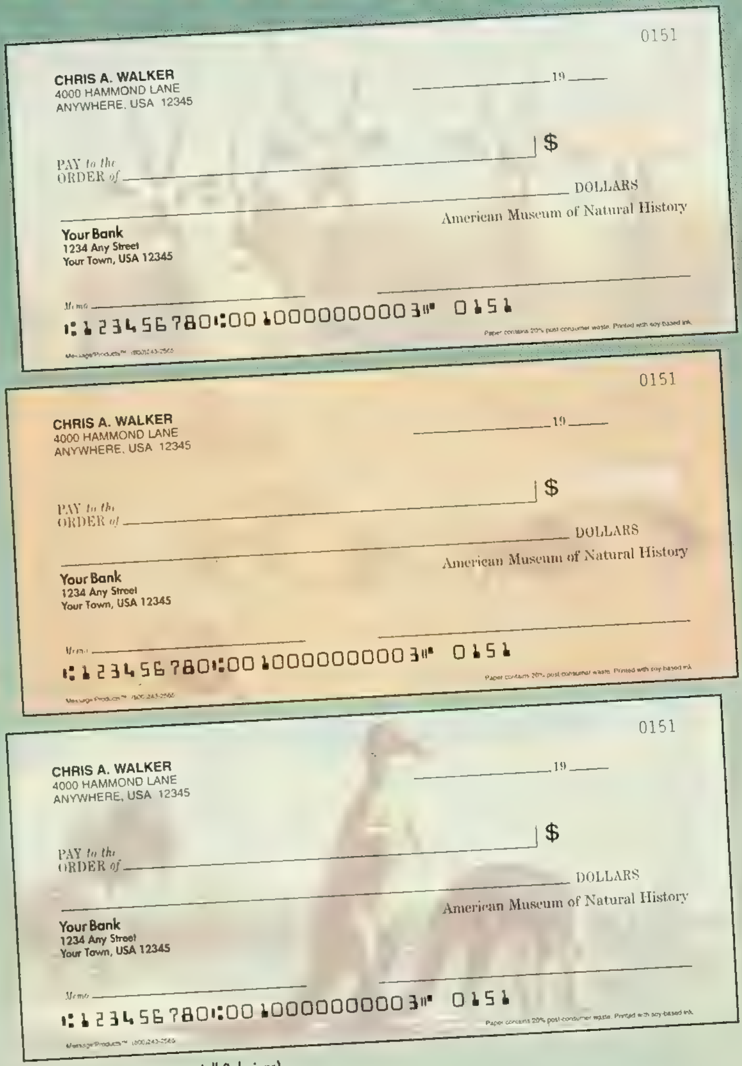

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INTERNET: http://www.envirolink.org/products/message from southeastern Tibet where these species are found.

October 24

On one of the wide streets of Peking, a fair was in progress. Here I saw several falconers with hooded goshawks on their wrists. These birds are used here for catching hares and game birds for the market—the price of ammunition to secure game being much greater than the market price of the game so that hawking is the method which alone can be successfully employed today.

October Events

"To the Ends of the Earth: Fossil Discoveries from the American Museum of Natural History" opens in Gallery 3 in early October and runs through the middle of December. Documents on display will include fossil finds, field memorabilia, archival film footage, and photographs. The first dinosaur specimen ever excavated by the Museum will also be exhibited.

Commemorating cultural diversity and scientific exploration in honor of the Museum's 125th anniversary, "Month of Sundays: A Celebration of Science and World Music" will feature free demonstrations, workshops, performances, films, and discussions. These events, which take place on October 8, 15, 22, and 29, include a "food as medicine" demonstration, a dinosaur dig, and music and dance from around the world. In a highlight of the events (scheduled to take place from Thursday, October 12, through Sunday, October 15, in the Hall of Mexico and Central America), Bolivian craftsmen Maximo and Erik Catari will construct a twenty-foot replica of an ancient reed boat that once sailed on Lake Titicaca.

On Sunday, October 8, visitors to the Museum can bring their finds—fossils, minerals, bones, insects, or artifacts such as baskets, crafts, or ornaments—to be examined by Museum scientists.

"Religions of a Diverse Society"—part of the Education Department's ongoing weekend series, "Multicultural Mosaic: Trends of a Diverse Society"—begins this month. In addition to lectures, panel discussions, and performances, the new series will present films from the ten-part TV documentary *Divine Magic,* which premières Wednesday, September 27, at 10:00 P.M. on the Discovery Channel.

For a complete schedule of these events, call (212) 769-5315.

FALL LECTURE SERIES

Great diamonds of the world will be the subject of a talk by Brigadier Kenneth Mears on Monday, October 2 at 7:00 P.M. Mears oversaw the safe-keeping of the British Crown jewels at the Tower of London from 1980 to 1989, and is the author of a book on the subject. Tickets are $10.

In a four-part series entitled "Avenues to the Past," ethnohistorian Robert S. Grumet

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and archeologist Joel W. Grossman look at the various ways people define time and interpret history. The series will take place on Thursday evenings, beginning October 5 at 7:30 P.M. Tickets for the series are $25.

Peter Gold, author of *Navajo and Tibetan Wisdom: The Circle of the Spirit,* will speak about connections between these two cultures on Monday and Tuesday, October 16 and 17, at 7:00 P.M. Tickets are $15.

British ornithologist and BBC producer Jeffrey Boswall will demonstrate—with whistles, pipes, blowers, and tape recordings—how humans reproduce the language of birds. His talk, "Human Mimicry of Bird Sound," will be held on Wednesday, October 25, at 7:00 P.M. Tickets are $10.

New Zealand artist John Bevan Ford will give a lecture on Maori art on Wednesday, October 25, at 7:00 P.M. Tickets are $10.

Volcanoes, their impact on the earth's climate and their geological processes, will be the subject of talks on four consecutive Thursday evenings, beginning October 26 at 7:00 P.M. Speakers include oceanographer ohn R. Delaney, of the University of Washington; oceanographer Haraldur Sigurdsson, of the University of Rhode Island; geologist Christopher G. Newhall, of the U. S. Geological Survey and the University of Washington; and geologist James W. Head, of Brown University. On October 31 and November 14, films featuring volcanoes will be shown at 7:00 P.M. Tickets for the series are $25 ($20 for students).

Call (212) 769-5310 for more information about the Fall lecture series.

MEMBERSHIP PROGRAMS

Forensic scientist William Maples, author of *Dead Men Do Tell Tales,* will give a talk on the subject of ancient and modern mysteries surrounding the dead on Thursday, October 5, at 7:00 P.M.

The myths and folklore associated with wolves will be explored by wildlife biologist Patricia Tucker and documentary filmmaker Bruce Weide in two talks scheduled for October 12. The speakers will bring their hundred-pound gray wolf and their shepherd-mix dog to both lectures, which will be held at 4:00 P.M. for children aged six and older and at 7:00 P.M. for adults.

Folklorist and author Adrienne Mayor will give a lecture on mythological griffins and their links with beaked dinosaurs on Thursday, October 26, at 7:00 P.M.

Storyteller Laura Simms will return to the Museum for the fourteenth year to tell ghost stories. The storytelling will take place on Friday, October 27, at 6:00 P.M. for children aged five through twelve and at 8:00 P.M. for adults.

Call (212) 769-5606 for details about all membership programs.

The American Museum of Natural History is located on Central Park West at 79th Street in New York City. For more information regarding the Museum's hours and admission fees, call (212) 769-5100.

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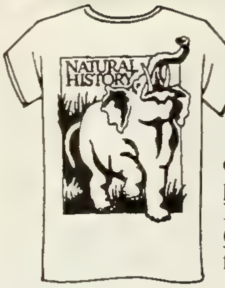

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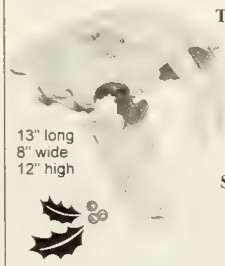

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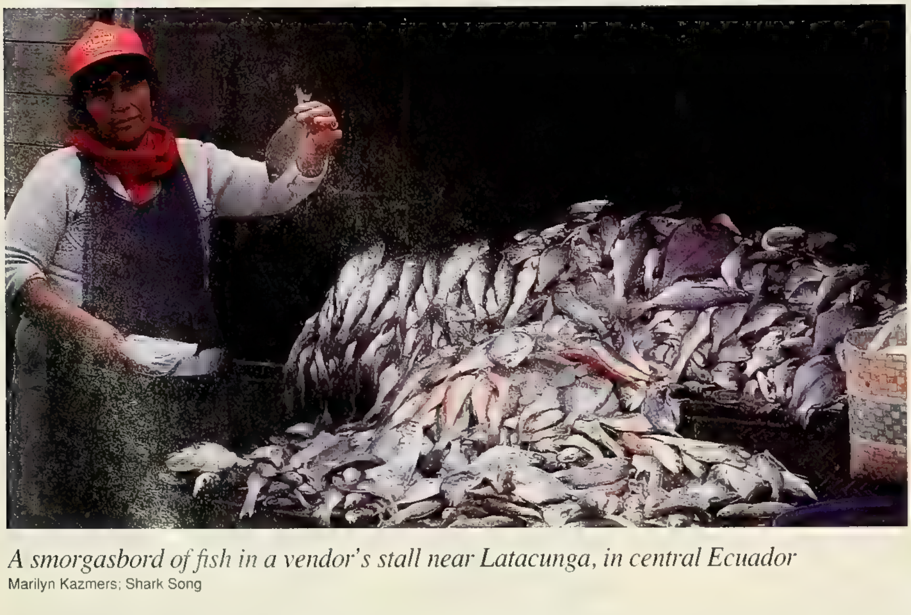

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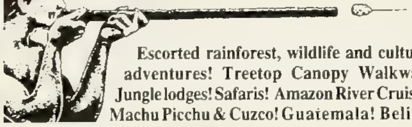

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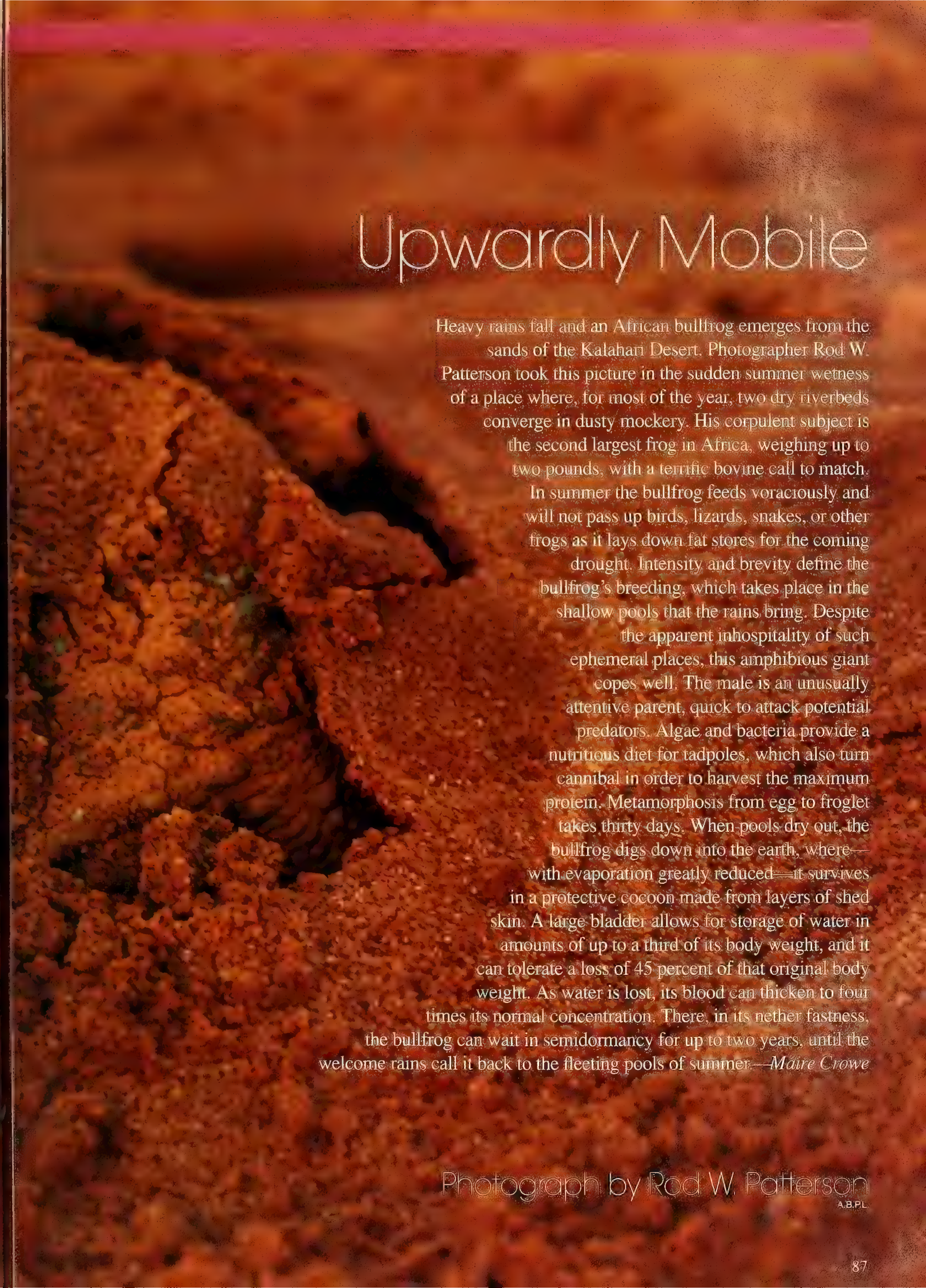

Upwardly Mobile

Heavy rains fall and an African bullfrog emerges from the sands of the Kalahari Desert. Photographer Rod W. Patterson took this picture in the sudden summer wetness of a place where, for most of the year, two dry riverbeds converge in dusty mockery. His corpulent subject is the second largest frog in Africa, weighing up to two pounds, with a terrific bovine call to match. In summer the bullfrog feeds voraciously and will not pass up birds, lizards, snakes, or other frogs as it lays down fat stores for the coming drought. Intensity and brevity define the bullfrog's breeding, which takes place in the shallow pools that the rains bring. Despite the apparent inhospitality of such ephemeral places, this amphibious giant copes well. The male is an unusually attentive parent, quick to attack potential predators. Algae and bacteria provide a nutritious diet for tadpoles, which also turn cannibal in order to harvest the maximum protein. Metamorphosis from egg to froglet takes thirty days. When pools dry out, the bullfrog digs down into the earth, where—with evaporation greatly reduced—it survives in a protective cocoon made from layers of shed skin. A large bladder allows for storage of water in amounts of up to a third of its body weight, and it can tolerate a loss of 45 percent of that original body weight. As water is lost, its blood can thicken to four times its normal concentration. There, in its nether fastness, the bullfrog can wait in semidormancy for up to two years, until the welcome rains call it back to the fleeting pools of summer.—*Máire Crowe*

Photograph by Rod W. Patterson
A.B.P.L.

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NATURAL HISTORY
Vol. 104, No. 11, November 1995

A Musical Issue

It is a memory that has remained with me for many years: a broad expanse of flat tidal land in southern New Jersey; flocks of migrating shorebirds, red knots and ruddy turnstones; and the voice of Sarah Vaughan. This was early spring, and somehow the running tide and the light breeze through the seedling spartina grass seemed a perfect accompaniment to the earthy, tremulous tones coming from the car stereo. Nature met music. Music had wings as well.

Of late, there has been a growing appreciation of the broad range of the world's music. Expeditions now go out to collect sounds—from the forests to the deep oceans, from bird song and whale song to the music of remote cultures. Jazz musicians jam with African herders. Record store racks are fairly bursting with world music. Ironically, this interest in international music seems to be growing in direct proportion to how quickly the cultures and places that create this music are disappearing. And there are those who rue the popularization of the discoveries and the increasing influence of modern, Western musical culture on those who until now have been untouched by electronics, synthesizers, and the demands of the music industry.

In this issue we introduce a new, regular feature to *Natural History:* "World Beat" (page 48), essays on the world of music and culture by Mark Jacobson. His first piece gives us a look at how the culture of Rasta and reggae in Jamaica has changed since the death of Bob Marley. Although fourteen years have passed, Marley remains a musical, cultural, and political icon.

Remembering Marley: Bragga, left, and Neville Garrick, director of the Bob Marley Museum in Kingston, Jamaica
Scott Thode

Last summer I was on a boat that was filled with recording equipment. Once offshore, we lowered microphones into the water to record the vocalizations of dolphins; onboard, loudspeakers played the sounds we picked up. Standing next to one of the speakers, a blind passenger listened intently. When we spoke, I asked him if he knew what a dolphin looked like. He had no visual image, he told me. The dolphin, he said, *was* its sound.

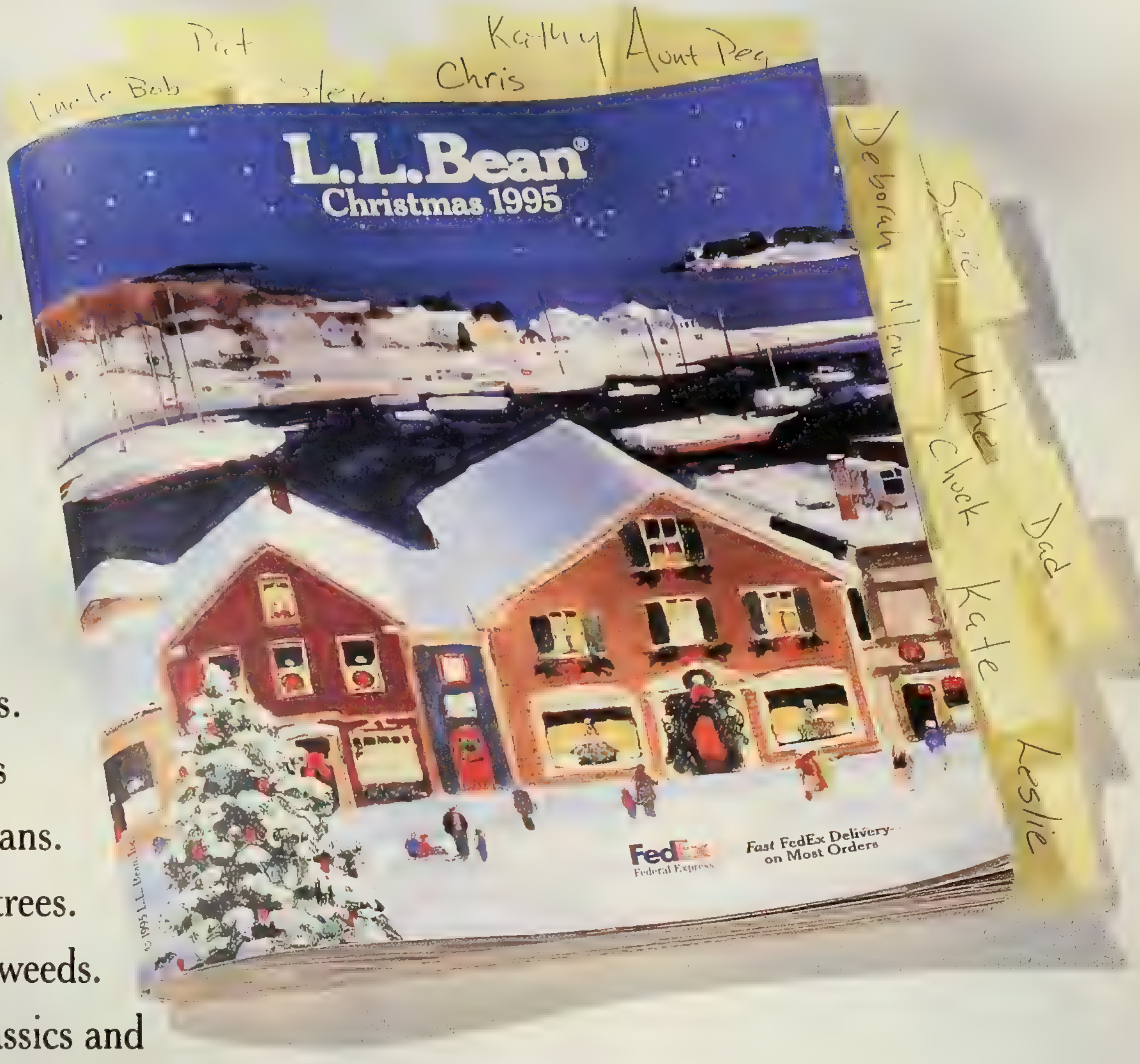
What drew photographer Lori Grinker to the little orchestra of blind women and girls in Cairo, Egypt, was the realization that it was through music that these instrumentalists made contact with the rest of the world. We get a look at their world through Grinker's intimate photographs ("Sounds of Light and Hope," page 34). Writer and musicologist Philip Schuyler relates how the lives of these students have come to revolve around the music that they play.

Music plays a leading role at Al-Nour wal Amal Association, a center for blind girls and women in Cairo.
Lori Grinker; Contact Press Images

Music has always been a way for people to make contact with and appreciate the worlds of nature and culture around them. Perhaps it can be another reason to preserve those worlds and their diversity.

Bruce Stutz

L.L. Christmas Tradition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LETTERS

Changes, Changes

The new graphic layout of the magazine is attractive, and I like the "Up Front" column. But the introduction of "Please turn to page..." messages is another matter. I've never understood the point of splitting articles in any serious magazine. I suspect that it is essentially meaningless in *Natural History,* whose readers, if they are anything like me, devour each issue from front to back. There's no need to catch our attention with the first couple of pages and then jump to the next article; our attention spans are longer than that. Please go back to printing each article in one place in the magazine.

William F. Falls
Arlington, Virginia

The editor replies: After a long period of remaining relatively unchanged, *Natural History* is evolving. Our aim is to retain our best features—the ones that got us where we are today—while adding new ones so that we will continue to thrive. We received many letters about the practice of "jumping" stories. Most were not in favor of it, and so whenever possible, we will let articles run without breaks. We look forward to your comments regarding all of our changes. In this issue, we add a new column, "World Beat" (page 48), on music and culture. Next month, we will bring back a favorite of *Natural History* readers, a column on the nature and culture of food, by Texas writer Robb Walsh.

Securing the Banana

Regarding "The Evolved Imagination," by Richard Dawkins (September 1995): my imagined baboon was a lazy, unimaginative baboon that, seeing the banana on the plank levered out over the precipice, ignored the rock as a counterbalance, grabbed the plank, pulled the banana in, and ate it . . . thus, perhaps, securing the heritage of lazy, unimaginative baboons.

Michael P. Smith
New Orleans, Louisiana

What's Normal?

I can't resist adding a slight correction to the stated value for normal human body temperature in Neil de Grasse Tyson's reply to Angelos Zompakos ("Letters," September 1995). Normal temperature, it turns out, is 98.2 degrees Fahrenheit (36.8 Celsius or 310 absolute), not 98.6° F. This was determined in recent studies involving millions of measurements. According to John Allen Paulos, in *A Mathematician Reads the Newspaper* (as reported in the August 18, 1995 issue of *Science*), the 98.6 value came about originally when earlier measurements were averaged and rounded off to the nearest Celsius degree, 37° C, and then converted to Fahrenheit.

Gaye Eisenlord
El Sobrante, California

Maya Overstatement

I was very pleased to read Fred Bruemmer's account of the massive arrival of sea turtles on a Costa Rican beach ("La Arribada," August 1995). However, I must take exception to the phrase "deeply rooted in the Maya culture of the area." Costa Rica does not have a Mayan cultural inheritance. The pre-Columbian groups that lived near Guanacaste (where the *arribada* takes place) were the Chorotegas. They inhabited what is called the Greater Nicoya, which included part of southern Nicaragua's Pacific region.

Hortensia Herrera-Bartlett
San José, Costa Rica

Costa Rica is, of course, to the south of the Maya area. An editing error introduced the mistake, for which we apologize.—*Eds.*

Spin-doctor Gould?

Perhaps Dr. Gould has overreacted to today's plethora of creationist spin doctors and, in an effort to counter the spin, generated an oversimplified counterspin of his own. His emphasis on "ultimate individualism" and the "reproductive success of individuals," with group and species success considered as mere "sequelae" in the process, left much to be desired ("Spin Doctoring Darwin," July 1995).

Let us consider insect colonies. Which is the successful individual: the queen, the soldier, or the worker—or is it the entire colony? And what are we ourselves if not cell colonies? Which cells are the key cells and which are secondary? Perhaps we must go even further to the DNA molecule and ask which are the key genes. Are these the ultimate individuals? The point is that just as a mammal becomes an "individual" as a result of the development and differentiation of individual cells, so, too, a group or species becomes an individual entity as a result of the development and differentiation of its various individual units.

GEORGE SHENKAR
Detroit, Michigan

TO TASTE A MUTTONBIRD

Irynej Skira tells us how muttonbirds are caught, killed, plucked, and frozen. But we were not told whose plate is the ultimate destination, how they are cooked, and what they taste like.

JAMES R. BIRD
Medford, New Jersey

IRYNEJ SKIRA REPLIES: The fresh birds are sold in Tasmanian butcher shops and take-aways; salted birds are exported to New Zealand, where they are popular among the Maori. Taste is very subjective. Some people hate them—in a shop they don't look very appetizing—but others love them. Among "Furneaux Island Recipes" printed in the *Aboriginal Newsletter* (Melbourne) are suggestions for baked, grilled, fried, or curried young birds and the following recipe for Old Bird Sea Pie:

Old Bird Sea Pie Ingredients

4 old muttonbirds (cleaned and gutted)
1 large onion
large carrot
1 large swede [turnip]
1 teaspoon each of salt and pepper
4 large potatoes
2 tablespoons fat (from fried birds)

Sea Pie Crust

3 to 4 cups [self-rising] flour
3 tablespoons fat
enough water for a scone mix dough

Method

Cut muttonbirds into quarters, place in a pot, add salt, pepper and fat and cover with water. Bring to the boil, then let simmer for $1\frac{1}{2}$ hrs. Peel and slice vegetables and add to pot, let simmer for $\frac{1}{4}$ of an hour, then add potatoes. Put into bowl flour, salt and fat. Rub fat into flour, add water and mix to texture of scone dough. Turn out on to floured board and roll out with rolling pin until it is the same size as the pot. Place dough on top of the muttonbirds, cut hole in middle of dough and let boil for another $\frac{3}{4}$ of an hour. Serve hot.

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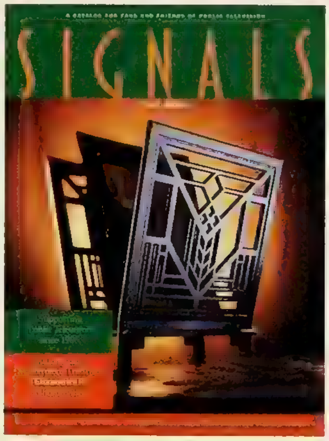

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AUTHORS

Delta Willis ("Leakey for President") was born in Arkansas, where the teaching of evolution was legally banned when she attended high school. Most of her working life has been spent producing nature films, travel books, and articles about evolutionary science. In 1982, Willis visited Africa (one of her twenty-three journeys there) and spent time observing paleoanthropologist Richard Leakey's digs. The result was her book *The Hominid Gang; Behind the Scenes in the Search for Human Origins* (New York: Viking Penguin, 1989). Willis's most recent work is *The Sand Dollar and the Slide Rule: Drawing Blueprints from Nature* (New York: Addison/Wesley, 1995).

A Paris-based freelancer, photographer **Gilles Saussier** ("Cloud Harvest") has spent the last six years traveling the world documenting environmental and political stories, from the gradual disappearance of the Aral Sea in the former Soviet Union to the plight of refugees in Bangladesh.

Ethnomusicologist **Philip D. Schuyler** ("Sounds of Light and Hope") was introduced to Al-Nour wal Amal Orchestra in Egypt by photographer **Lori Grinker**. An associate professor of music at the University of Maryland, Baltimore County, Schuyler is fluent in Arabic, having done fieldwork on the music of Morocco and Yemen. Lori Grinker (shown attempting to play the violin) had a photo essay about a young boxer published by *Inside Sports* in 1980, while she was still a student at Parsons School of Design in New York. At that time, she met another young boxer, Mike Tyson, whose life she documented for the next decade. Her accomplishments include a series of photographs on war veterans, "In the Footsteps of the Dead." Her first book, *The Invisible Thread: A Portrait of Jewish American Women,* was published in 1989.

Cambridge-born **Bill Amos** ("Blood Relations") went to Oxford University to get his B.A. in zoology but returned to his native town's university for doctoral and postdoctoral work in genetics. Still based at Cambridge, he heads the Molecular Ecology Group in the university's genetics department and is now applying molecular techniques to questions about marine mammals. He also runs a large and active research group whose members are studying a wide range of species, from parasite-ridden sheep on a remote Scottish island to Peruvian and antarctic fur seals to Hawaiian humpback whales.

Mark Jacobson ("Bob Marley Live"), who met the King of Reggae twenty years ago, is a contributing editor of *New York Magazine* and *Esquire*. Jacobson, who lives in Brooklyn, New York, with his wife and three children, is also a novelist and screenwriter. (He describes his 1991 novel *Gojiro* as "a postmodernist meditation on the atomic bomb from the point of view of a Godzilla-like monster.") With this issue, he launches "World Beat," his column for *Natural History,* which will cover cultures through popular (and unpopular) music.

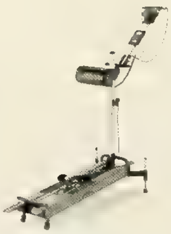
Simon Pollard ("A World Apart"), a researcher at New Zealand's University of Canterbury, has traveled widely in Southeast Asia studying and photographing the behavior of spiders. He is currently absorbed with spiders' feeding mechanisms and secondary sex characteristics.

"The absolute highlight of my Kenya trip," says German photographer **Uwe Walz** ("Talons versus Tusks") "was documenting a battle between an eagle and a wart hog." He feverishly snapped pictures as the event unfolded and took the last picture just as the wart hog was driven off. A semiprofessional photographer for more than fifteen years, Walz's work has taken him throughout Europe and to Africa, the United States, and Canada, and his photographs have appeared in nature magazines such as *Cosmos* and *Geo.* He captured the unusual clash with a Canon EOS-1 camera and 600 mm lens.

I want to run with my dog again.

Jim Parker, age 55

I want to surprise my doctor with my next checkup.



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Leakey for President?

The man who unearthed some of Africa's oldest humans is battling to play a major role in Kenya's future

by Delta Willis

Last May, when Richard Leakey announced that he was helping to form a new political party in Kenya, no one who knew him well was surprised. Within the fiercely competitive world of paleoanthropologists, Leakey had long been regarded as a successful empire builder. When he was in his twenties, his expeditions and discoveries of early human remains in Kenya's East Turkana region had already begun to overshadow those of his father, the legendary Louis Leakey. In 1969, Richard convinced Kenya museum trustees to merge his father's Centre for Prehistory and Paleontology with the National Museum, with Richard as overseer of both. The long-standing animosity between the two men would last nearly until the father's death, in 1972. In 1989, Kenyan president Daniel arap Moi selected Leakey to head the Kenya Wildlife Service, a key government agency in a country highly dependent on foreign currency brought in by tourists on wildlife safaris. Critics say this became part of a fiefdom Richard had begun developing as director of the National Museums.

The new opposition party is called Safina, Swahili for "boat" but also signifying Noah's ark. "The idea," Leakey said, "is that we're gathering everyone together for a fresh beginning. . . . The country is slipping backward and something has to be done about it." Although Leakey denies he plans a run for the presidency in Kenya's next election in 1997, his younger brother, Philip, the first white elected to parliament and a Moi supporter, thinks otherwise: "He's been telling people since he was fourteen years old that he wants to be president."

Moi has denounced Leakey as a "racist colonialist" with "foreign" ties. But even Philip defended him from that particular charge: "Arrogant, yes. Racist, no."

On August 10, Richard Leakey and several of his supporters were assaulted outside the law courts in Nakuru, an industrial town in west central Kenya, as they attempted to visit a jailed member of their party. A group of protestors broke the windows of Leakey's car, beat and whipped him, and injured several of his associates and some journalists so badly that they were hospitalized. Police in riot gear apparently observed the assault but stood by without taking action. The government later denied that the attack had been organized by the ruling party, the Kenya-African National Union (KANU)—although many in Kenya, and for several good reasons, thought otherwise.

As head of the Wildlife Service, Leakey built up a platoon of armed rangers, successfully brought an end to the slaughter of Kenya's elephants, and made a huge public bonfire of confiscated tusks. But Leakey's crackdown on poachers and the dismissal of employees he charged with being corrupt or incompetent made him the object of death threats. He began to travel with armed bodyguards.

Leakey's success in stemming poaching and restoring morale to a beleaguered agency was matched only by his ability to raise $150 million for the Service. Leakey said he resisted demands from two government ministers for an oil pipeline and a mine within the national parks. The sudden growth in Leakey's power and resources began to worry some government ministers. William ole Ntimama, minister of local government, complained to the Nairobi press that "Leakey has disregarded our human rights and upheld the rights of animals to kill us."

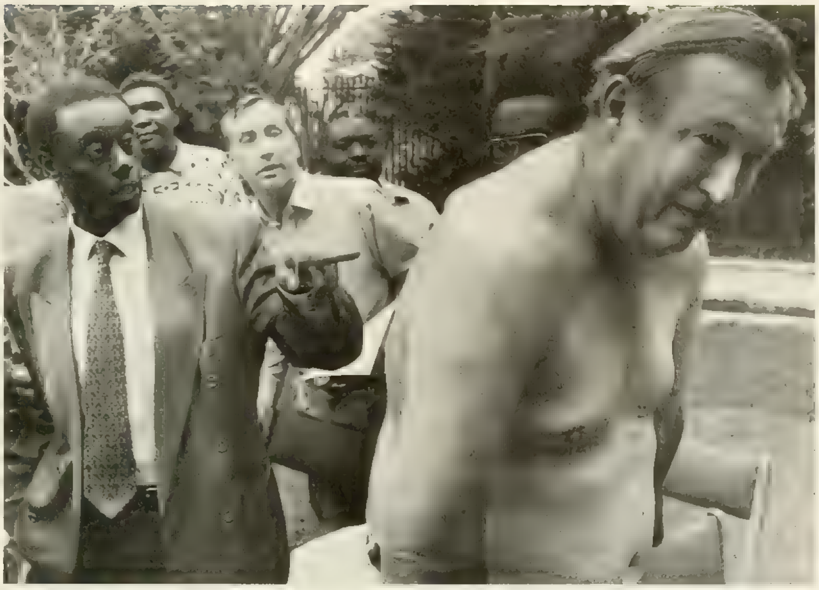
"I was made director of wildlife," Leakey later retorted, "not director of social service [or] agriculture."

But his influence extended far beyond wildlife. As director of the National Museums of Kenya for more than two decades, Leakey had administered its many departments and delegated much of the search for, and analyses of, fossils to others. He had also helped shape Kenya's Antiqui-

In 1989, Richard Leakey cheerfully presided over a public bonfire of confiscated Kenyan elephant tusks worth about $3 million. His war on poachers was backed by Kenyan president Daniel arap Moi, now his political enemy.

Tom Stoddart; Katz Pictures/SABA

ties Law and refined the requirements for visiting scientists.



Paul Muite, a founding member of the Safina party, points to lash marks on Richard Leakey's back. On August 10, 1995, Leakey was severely beaten by young thugs while police looked on.

Jacob Waweru

Louis Leakey, too, had been active in Kenyan politics. He was as familiar with the language of the Kikuyu farming people as he was with English. As a teenager he was initiated into the Kikuyu and later expressed sympathy for their grievances against the government. Later, however, his linguistic skills were employed by the colonial government during the Mau Mau uprising, and in 1952 he served as an interpreter at the trial of Jomo Kenyatta, a member of the Kikuyu tribe. When Kenyatta was convicted and jailed, Louis feared retribution. But Kenyatta, Kenya's first president after independence in 1963, forgave Leakey and encouraged the family's continued research.

In June of 1993, Richard's single engine Cessna lost power and crashed shortly after takeoff. As a result of his injuries, Leakey lost both legs below the knees. Some suspected sabotage, but no evidence was found in the wreckage. A few months later, Kenya Wildlife Service employees cheered as Leakey walked back to work on prostheses, without a cane. President Moi apparently grew uneasy about this loyalty; the well-equipped Wildlife Service rangers and antipoaching team looked like the beginning of a private Leakey army on a continent where military coups are commonplace.

Forming a new party in Kenya is not an easy undertaking. In 1982, the country's constitution was changed to limit opposition to the ruling KANU party. Additional limitations were proposed this past summer in a bill Leakey said was "clearly designed to change the ground rules"; the bill has not yet passed.

Two decades ago, Kenya was considered an island of peace and prosperity in Africa, but population increases, the proliferation of automatic weapons, and an upsurge in crime and corruption have taken a toll. Kenyan journalists who have written openly about political corruption have been jailed.

Kenya's first attempt at a multiparty election, in 1992, saw opposition groups splinter. When Safina was formed, the incumbent KANU party reacted swiftly, harassing Richard's older brother, Jonathan, and arresting activist lawyer Paul Muite. It was also suspected of orchestrating a raid on Richard's home led by Masai warriors armed with traditional weapons.

"Richard is my brother," says Philip, "but . . . we will remain opponents until he gets smarter politically. Unfortunately, he allies himself with radicals who advocate civil disobedience and other confrontational tactics. I think he'd accomplish much more by working within the system." Meanwhile, the government has continued to delay granting recognition to Safina, effectively cutting off access to television and radio campaigning.

Leakey says he was forced to resign from the Wildlife Service in 1994 because of lack of government support. At the same time, President Moi forced him out of his position as a trustee of the National Museums, where his wife, Meave, remains head of paleontology. Now he has also been attacked in print by two of his former colleagues at the National Museums. A few months ago, former museum artist Eustace Gitonga and paleontologist Martin Pickford published a book entitled *Richard Leakey, Master of Deceit,* a vitriolic diatribe characterizing Leakey as someone who was "capable of talking a hyena out of a carcass."

After the August attack, an undaunted Leakey, displaying the welts on his back for the press, said he would not be deterred. "I think they were trying to kill me," he said. "If they do, I believe it would further the process of change." □

A Sea Horse for All Races

When Huxley battled Owen about human brain structures, the debate grew convoluted

by Stephen Jay Gould

Richard Owen, the great English anatomist, awaited with keen anticipation the monthly installments of Charles Dickens's latest novel *Our Mutual Friend.* Owen needed no special reason to join his countrymen in reading the serialized work of England's most beloved writer. But Owen did have a personal stake in the new book, for Dickens had shaped the character of Mrs. Podsnap for his scientific friend: "a fine woman for Professor Owen, quantity of bone, neck and nostrils like a rocking-horse, hard features, majestic head-dress in which Podsnap has hung golden offerings."

Our Mutual Friend appeared in full form in 1865. In the same year, perhaps in specific gratitude, but perhaps only to acknowledge their general friendship, Owen inscribed a copy of his newly published "Memoir on the Gorilla" to "Charles Dickens, Esq. from his friend the Author." I regard my ownership of this copy as a rare and precious privilege. Dickens made no annotations, but a bookplate on the cover, presumably inserted as a come-on for a sale after Dickens's death in 1870, does prove that Owen's friend kept and shelved the book: "From the library of Charles Dickens, Gadshill Place, June 1870." Owen and Dickens knew each other primarily from that bastion of Victorian connectivity among males of good breeding or accomplishment (sometimes even both): club life. They met most frequently at the Athenaeum, the major London club for intellectuals (both Darwin and Huxley belonged as well). The Athenaeum still exists and still excludes women from several of its spaces. Traditions and memories, both good and bad, die hard. I was once shown the very spot on the main staircase where Dickens and Thackeray almost came to blows.

In our post-Dian Fossey world, gorillas have become familiar, if continually fascinating. But in Owen's day, mystery and novelty increased the allure of these largest apes. Chimpanzees had been known for more than a century (the London physician Edward Tyson had written a classic monograph on chimp anatomy in 1699), while Dutch ships had brought orangutans back from Indonesian colonies. But the gorilla, although featured in numerous legends, did not prove its existence to scientists until 1846, when Thomas Savage, an American missionary, obtained some skulls in Gabon. Owen, who had published many papers on the anatomy of other apes and monkeys, narrowly lost the race for priority in identifying and naming the gorilla, when the French anatomist Isidore Geoffroy Saint-Hilaire and the American physician Jeffries Wyman barely beat him into print.

But Owen, as chief of natural history at the British Museum, had maximal access to new specimens. In 1851, he had received the first complete skeleton to reach England, followed in 1858 by a nearly full-grown male preserved in spirits. In 1861, the museum purchased a collection of skins for mounting and exhibition, including specimens of females, males, and young shot by the explorer Paul B. du Chaillu. Owen, therefore, had both the skills and the material to become the first great scientific expert on gorillas—and he accepted the challenge in many publications, culminating in his 1865 monograph.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University. He is also Frederick P. Rose Honorary Curator in Invertebrates at the American Museum of Natural History.

Owen had the skins, muscles, and bones, but knowledge of behavior and ecology still depended upon unconfirmed reports of African travelers. Du Chaillu himself tended to skepticism. He regarded gorillas as mostly herbivorous (correct, as we now know), despite numerous reports of frightening carnivory. Owen writes in 1865:

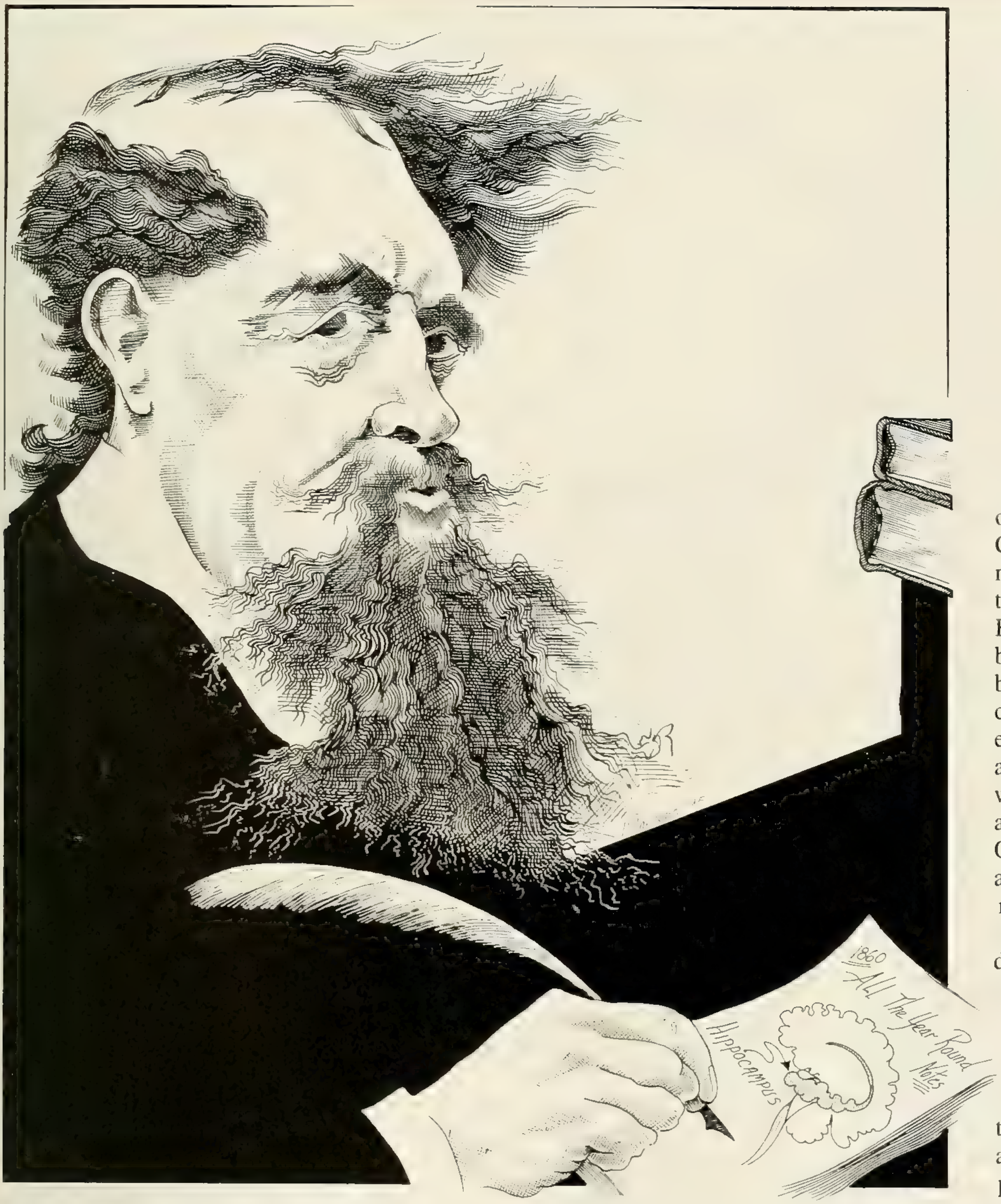
> Mr. du Chaillu, however, states that he examined the stomachs of the Gorillas killed by himself and his hunters, and "never found traces there of aught but berries, pineapple leaves, and other vegetable matter." The Gorilla is a huge feeder, as its vast paunch, protruding when it stands upright, shows.

Owen reports the lurid stories that du Chaillu heard from local people:

> Mr. du Chaillu also adduces the testimony of the natives, that, when stealing through the gloomy shades of the tropical forest, they become sometimes aware of the proximity of one of these frightfully formidable Apes by the sudden disappearance of one of their companions, who is hoisted up into the tree, uttering, perhaps, a short choking cry. In a few minutes he falls to the ground a strangled corpse. The Gorilla, watching his opportunity, has let down his huge hind hand, seized the passing Negro by the neck with vise-like grip, has drawn him up to higher branches, and dropped him when his struggles had ceased.

But Owen also reports du Chaillu's personal dubiety: "There is no doubt the Gorilla can do this, but that he does it I do not believe."

Du Chaillu's 1861 book, *Explorations in Equatorial Africa,* precipitated one of the greatest fracases in the contentious world of Victorian science. Many naturalists accused du Chaillu of fabricating tales; some suggested that he had never even visited the habitat of gorillas but merely bought material shot by others (du



Vint Lawrence

Chaillu, for example, had written a dramatic account of shooting a large, enraged and charging male—but the skin, shipped to Owen in London, bore no bullet holes in front). Debate also raged on du Chaillu's claim for personal observation of a stunning habit that has defined our image of male gorillas ever since—pounding on the chest to display threat or anger. Owen reports the claim:

> When so pursued as to be driven to stand at bay, the Gorilla, like the Bear, raises himself on his hind feet, with his powerful arms and hands free for the combat. In this predicament Mr. Chaillu affirms that the creature "offers defiance by beating his breast with his huge fists, till it resounds like a bass-drum."

In deference to both sides at once, and maintaining all options in the face of doubt, Owen then commented:

> There is nothing in the structure of the Gorilla, save the size and depth of the chest, to suggest or accord with this peculiar action. Nor, were the dog as rare a beast, is there anything in its anatomy that would have suggested, to one who had never seen it alive, its occasional habit of running on three legs. In statements of this kind by a traveller, it is neither wise to discredit nor implicitly to believe; but one may acquiesce, and wait the report of succeeding observers whose attention has been directed to the original statement.

Most lurid legends turn out to be wrong, but du Chaillu was vindicated: male gorillas do pound their chests, just like King Kong (but more in bluff than in prelude to battle). In fact, although du Chaillu did not emerge as a paragon of accuracy, he did fare well in the great debate, and he and his mentor Owen clearly won both a palm of victory and the right to thump.

As a curious footnote, du Chaillu's supporters also included a man so hostile to Owen, both for irreconcilable views and opposite personalities, that I doubt they ever again shared a common platform: England's most eloquent naturalist, Thomas Henry Huxley. Although Huxley found du Chaillu's book full of unintentional errors based on "imperfectly kept notes" and "a rather vivid imagination," he honored du Chaillu's courage in visiting dangerous and inaccessible places, and he found the explorer's accounts generally reliable. (Huxley later backed off in supporting du Chaillu, for he rankled at the mileage accruing to his enemy Owen and just couldn't bear to act as an aide de camp.)

Strange bedfellows do not only inhabit political hotels; science also spawns odd allegiances. Huxley and Owen could work together on du Chaillu's behalf because both needed information about gorillas to pursue their own disparate campaigns—based in large part on attempts to slaughter each other.

Owen published his major work on gorillas in the 1865 monograph given to Dickens and in his Rede lecture of May 1859—"On the classification and geographical distribution of the Mammalia, to which is added an appendix 'On the Gorilla,' and 'On the extinction and transmutation of Species.' "—ironically published in the same year as Darwin's *Origin of Species,* for Darwin's book would so recast the debate to Owen's disadvantage. Huxley featured gorillas in his finest and most influential publication, a landmark in the history of scientific prose—"Evidence as to Man's Place in Nature," a series of lectures originally given to working men in 1860 and 1862 (admission supposedly required proof of blue-collar status, but legend—apparently true—tells us that Karl Marx sneaked in!).

The grand Darwinian debate on evolution may have defined the broad subject of these volumes by Huxley and Owen, but their own excruciatingly bitter personal confrontation about apes and humans forms the controlling subtext for all these documents—and one cannot understand these works today without some background in "the great hippocampus debate." (Victorian scientists did pursue activities other than contentious argument, although the three altercations that act as pillars of this essay do form a totality—du Chaillu's gorilla rhubarb and the Huxley-Owen hippocampus rumpus as stalking-horses for the grandest of underlying issues, Darwin's brouhaha on the origin of species.)

I write this essay to memorialize the centenary of Huxley's death in 1895. The hippocampus debate has always been depicted as Huxley's greatest and absolutely unalloyed victory. I am also an unabashed Huxley fan, as illustrated by numerous essays in this series. As a fierce defender of evolution ("Darwin's bulldog" in the cliché) and the greatest prose stylist in the history of British science (although one might argue for a tie with D'Arcy Thompson, author of *On Growth and Form*), Huxley almost has to be my personal hero. Nonetheless, and following the antihagiographical bent of these essays, I choose the hippocampus debate to memorialize Huxley because I believe that the story has not been fairly told—and that, at one crucial point agonizingly relevant to current concerns, Owen developed an important and valued argument against a baleful implication of Huxley's generally admirable stance.

Many advantages accrue to the victors of any dispute, military or cerebral—and chronicling rights must rank among the greatest of perks. In short, the winners write history. How would we interpret the Trojan War if our main account had been written by Hector's bard; and how would future generations view the history of evolutionary theory if Duane Gish and Henry Morris (our most vociferous modern creationists) cornered the market for written descriptions?

Richard Owen (1804–92) was the greatest anatomist and paleontologist of his age. His accomplishments were legion, both in range and excellence (including an early monograph on the chambered nautilus; the initial description of the oldest fossil bird, *Archaeopteryx;* a series of crucial papers on the moas, extinct giant ground birds of New Zealand; the first description of South American fossil mammals brought back by Darwin from his *Beagle* voyage; coining of the name "dinosaur," followed by volumes of accurate work on fossil reptiles of all ages). As a pillar of establishment science (and an intimate of Queen Victoria and nearly everyone else who mattered), Owen also wielded substantial power in the service of zoology, particularly in his long and successful campaign to establish a separate building for natural history within the British Museum. (Owen served as first director, and his edifice still stands, vigorously functioning in South Kensington as both a great monument of Victorian architecture and one of the most important scientific museums in the world.)

The great hippocampus debate focused on human uniqueness: Are we just improved apes or something different?

But Owen ran afoul of the ultimate victors in Victorian natural history—Darwin's circle. He was, to say the least, not a consistently nice man—genial and accommodating as could be to those more powerful than himself but arrogant and dismissive toward juniors and underlings, the folks who eventually "grow up" and write histories! He was not opposed to evolutionary ideas, despite later legends constructed by Darwinian chroniclers, although he strongly disliked Darwin's materialistic version of biological change.

The ever-genial Darwin wrote a most uncharacteristic assessment in his *Autobiography,* thus illustrating the off-putting power of Owen's personality:

> I often saw Owen, whilst living in London, and admired him greatly, but was never able to understand his character and never became intimate with him. After the publication of the *Origin of Species* he became my bitter enemy, not owing to any quarrel between us, but as far as I could judge out of jealousy at its success. Poor Dear Falconer [a paleontological colleague], who was a charming man, had a very bad opinion of him, being convinced that he was not only ambitious, very envious and arrogant, but untruthful and dishonest. His power of hatred was certainly unsurpassed. When in former days I used to defend Owen, Falconer often said, "You will find him out some day," and so it has passed.

As a young man, eager to advance, Huxley bridled under Owen's power—and bided his time. Huxley, twenty years Owen's junior, often needed letters of recommendation from the purveyor of maximal patronage in natural history. Owen always complied, and with strong words of praise much to Huxley's advantage, but he always made Huxley wait and treated him with condescension, if not contempt. Huxley recalled meeting Owen accidentally on the street after two unfulfilled requests for an urgently needed recommendation:

> I was in a considerable rage. . . . I was going to walk past, but he stopped me, and in the blandest and most gracious manner said, "I have received your note. I shall grant it." The phrase and the implied condescension were quite "touching," so much so that if I stopped for a moment longer I must knock him into the gutter. I therefore bowed and walked off.

Huxley and company eventually won rights to tell the official story, and they read Owen out of their triumphal account or (even worse) depicted him as a pompous fool and an unwitting agent of their victory. But Owen has found modern defenders among historians out to debunk progressivist accounts of science as con-

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tinuous advance fueled by saintly advocates of factual truth against infidels mired in social prejudice; Nicolaas A. Rupke's *Richard Owen: Victorian Naturalist* (Yale University Press, 1994) provides a splendid account in this corrective mode. Rupke quotes several genuine and warmly enthusiastic accounts of Owen, from many sensible and admirable people (including Charles Dickens). Let us just acknowledge that Owen was an enormously complex, brilliant, and fascinating man—and that the history of biology in Victorian Britain cannot be told without granting him a long chapter.

The great hippocampus debate began two years before Darwin published the *Origin of Species* and did not invoke natural selection as a central subject. But this most famous Victorian scientific wrangle did engage the primary, and perpetually gut-wrenching, subject that Darwinism placed in such sharp focus: the uniqueness of humans among other animals. Are we just improved apes or something entirely different from all other creatures? Huxley advocated continuity with gorillas; Owen defended sharp separation. The turf of battle, by Owen's choice and initial proposal, centered upon three structures in the brain. Owen claimed that only humans possessed these features, thus defining our absolute separation from the brute creation. Huxley proved that apes possessed versions of all three structures—sometimes as prominently expressed as in humans—and that Owen's marks of separation therefore affirmed our evolutionary unity with other primates.

> Owen claimed that only humans possessed three unique brain structures. Huxley demonstrated that all were present in other primates.

For the first difference, Owen claimed that only humans possessed a "posterior lobe" of the cerebrum—a backward extension of this traditional location for "higher" mental functions—covering the cerebellum, or conventional region for control of motor activity. (In a diagram accompanying Owen's 1859 lecture, the chimp cerebrum stops in front of the underlying cerebellum but extends to cover the brain's entire upper surface in humans. According to modern neurological findings, the traditional attributions of function are as wrong as Owen's claims for morphological differences, but I cite the older views to situate the debate in its own time. Obviously, if the "higher" cerebrum covered the "lower" cerebellum only in humans, we might measure our mental superiority thereby.)

Second, Owen stated that only humans possessed a posterior cornu in their lateral ventricle. (To explicate this mouthful, ventricles are spaces within the brain, continuous with the central cavity of the spinal cord and formed as the developing brain undergoes complex bending and folding in embryology. *Cornu* is Latin for "horn"—so the posterior cornu is a horn-shaped rear end to a cavity in the brain.)

Third and last, Owen claimed that only

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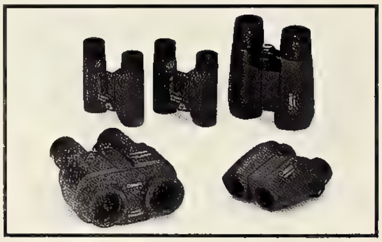

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humans developed a "hippocampus minor"—a ridge on the bottom of the same posterior horn of the lateral ventricle, produced by a deep inward penetration of an adjacent part of the brain called the calcarine fissure. This hippocampus minor is not the same structure as the hippocampus itself, an important region of the brain's old interior, recently identified in a series of elegant experiments as a site for the initial recording of short-term memories, which are then somehow transferred to the neocortex for long-term storage. In modern terminology, *hippocampus minor* has been dropped in favor of the earlier name *calcar avis,* or "cock's spur," in reference to visual similarity to the weapon on a rooster's leg that promotes the "sport" of cockfighting. The name "hippocampus" was originally coined in the sixteenth century by Arantius, a student of Vesalius, because the structure reminded him of a sea horse—*hippocampus* in Latin, the formal name later chosen by Linnaeus to name the major genus of sea horses.

I will not rehearse the details of the hippocampus debate here, for no story in Victorian natural history has been told so often and the basic facts are not in dispute. (My friend and colleague Charles G. Gross, professor of psychology at Princeton, has recently published a particularly clear and accessible article, notable for its focus on anatomical details of the brain—for Gross is a celebrated neurologist, not a historian: "Hippocampus Minor and Man's Place in Nature: A Case Study in the Social Construction of Neuroanatomy," published in *Hippocampus* [yes, in our world of specialization, each region of the brain has a journal devoted to its study], vol. 3, pp. 403–16.)

The debate arose in the late 1850s and lasted with full force into the 1860s, sputtering out by the time Owen wrote his gorilla monograph in 1865. Owen and Huxley duked it out both in writing and public appearances, notably at the same 1860 British Association meeting where, according to legend and unsupported by fact (see my essay in *Natural History,* May 1986), Huxley also destroyed Bishop "Soapy Sam" Wilberforce in an initial altercation over Darwinism (the exchange took place, but without a clear victor).

The debate spilled vigorously and copiously into general culture, as the public and press delighted in watching two of Britain's greatest scientists acrimoniously debating such an important issue (the status of humans in nature) by wrangling about parts of the brain unknown to all and endowed with such wonderfully amusing names as "hippocampus minor." Charles Kingsley, featuring the hippocampus debate in his contemporary children's classic *The Water Babies,* emphasized the humor implicit in the conjunction of arcane anatomical mumbo jumbo with a theme of such conceptual and emotional importance. Kingsley wrote of Professor Ptthmllnsprts (Put-them-all-in-spirits), his parody of Huxley:

> He held very strange theories about a good many things. He had even got up once at the British Association, and declared that apes had hippopotamus majors in their brains just as men have. Which was a shocking thing to say; for, if it were so, what would become of the faith, hope, and charity of immortal millions? You may think that there are other more important differences between you and an ape, such as being able to speak, and make machines, and know right from wrong, and say your prayers, and other little matters of that kind; but that is a child's fancy, my dear. Nothing is to be depended upon but the great hippopotamus test.

On May 18, 1861, *Punch* published a

Please turn to page 72

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Chacun à Son Gout

Bring on the cherries and charcoal

by Roger L. Welsch

The closest I come to being rich is that I have gout, the rich man's disease. I can't imagine why gout has gotten the reputation of being an affliction of the rich. It can result from a high-purine diet, which includes things like liver, beans, and chicken—not the first foods that come to mind when I think of Donald Trump's table. The impression that gout is a man's affliction, however, is more accurate: it is ten times more common among men than women. And from my personal experience (with the gout), it is also about ten times more painful than such female problems as childbirth. I realize there may be some debate about this, but to me it's as plain as the big toe on my foot.

And that is where gout strikes more often than not—the toes. Other favorite spots are the knees, ankles, wrists, or fingers. Gout chooses those places because that is where it can cause the most discomfort.

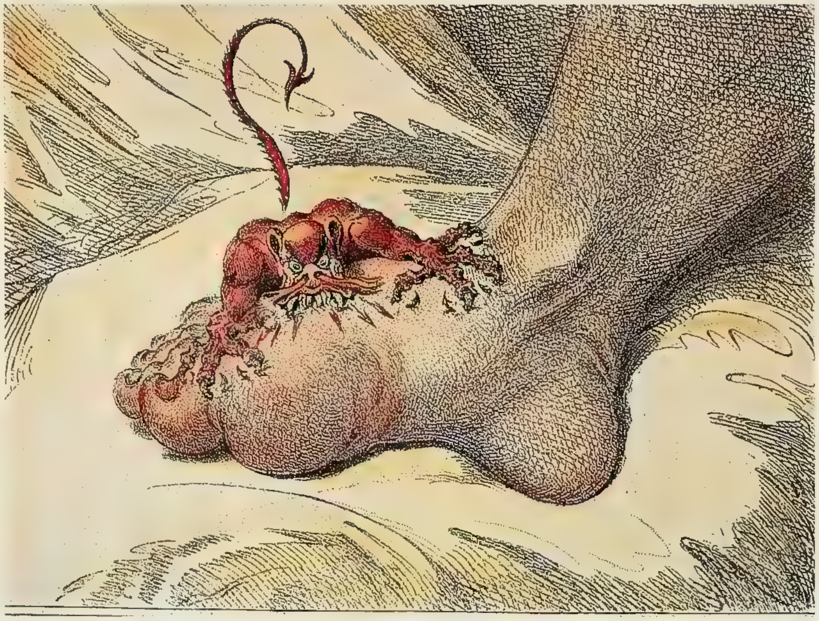
What happens is that your system loads up with purine. Purine has to go somewhere when there's no more room for it, so it forms uric acid crystals the general size and shape of a barrel cactus, a porcupine, or the spiny head of a medieval mace. And there the crystals sit, inside your big toe, right where you have to walk on them. Or especially in my case, in my left knee, which I have come to rely on pretty heavily when I do things like walk. Instead of having nice, smooth, slick surfaces working like ball bearings in all those places of your body that have to bend and flex, you've got a kneeful of cockleburs.

You'd think maybe you could rub the swollen, red, throbbing joint with a good liniment, right? Ha! The very idea of touching the joint is agony. Maybe a good dose of aspirin would be just the thing. Nope. Aspirin only makes the condition worse. How about a bottle of good wine or a couple of cold beers? Wrong again—they make it worse, too. Medical science has pretty well established that when it comes to gout, anything that sounds as if it might be good for it, isn't.

So what does medical science suggest? "Relax and elevate the affected joint." You are wallowing in pain, and they want you to relax. "Apply ice." Buddy, you're not applying anything to that knee, and I mean it. "Don't wear tight shoes." Duh. "Watch your diet." Right. If I lay off liver and beans stewed in beer, the pain should go away in, oh, a year or two.

Thank goodness, there are alternative treatment systems. If you suffer from gout, you know that all you have to do is limp around awhile—whimpering, cursing, threatening to shoot anyone who comes closer than ten yards to your left knee—and someone is bound to offer up the usual folk remedies: cherries and charcoal.

Cherries strike me as a medication I can get along with. The traditional wisdom has it that any sort of cherries will do—sweet or sour, canned or fresh, cooked or raw. Recommended doses run from "a handful" to "all you can eat." I like to think that cherries packaged in a way to facilitate the maximum intake by the patient would be best. Cherry pie comes to mind. Or a handful of maraschino cherries floating in a tall, cold Tom Collins.



The Gout, *an etching by James Gillray, 1799*

The Granger Collection, New York

Charcoal is another matter. I tried charcoal briquets with milk and sugar, white gravy, chocolate frosting, gin, even a nice béarnaise sauce (one at a time, not all together), and I think I can say with some certainty that there's no condiment you can put on charcoal, no matter how good, that lends any noticeable gastronomic improvement to it. I even tried charcoal with cherries. Nothing.

Anyone who has seen me at work at my barbecue grill, however, knows there is more than one way to get charcoal into your system. When I'm cooking on the patio, an extra gin and tonic, a lively conversation with a buddy, or a good article in a good magazine almost guarantees at least one of the steaks or burgers sizzling over the cooking coals—maybe all of them—will develop a generous amount of charcoal around the edges. On one occasion, our local volunteer fire department wound up helping me serve some hamburgers that spent a little too much time on the grill because I was tossing a Frisbee for our black Lab, Thud ("the name he earned with his head").

And so The Welsch Strategy for Battling the Gout begins to take shape—a Tom Collins with a couple of extra cherries, a filet on the grill acquiring a blackened patina, cherry pie a la mode (preferably with black cherry ice cream), polished off with a snifter of kirsch. I don't know what all this will do for my throbbing knee, but it makes me feel better just to think about it.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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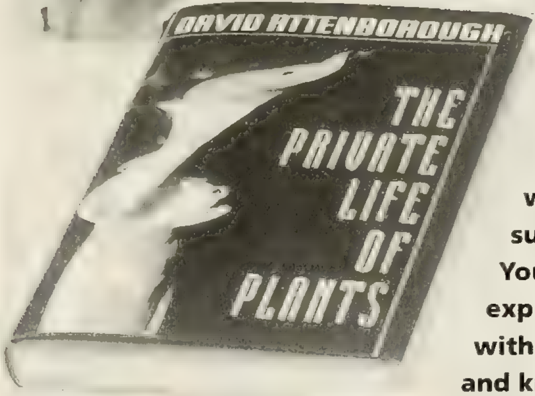
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Tide and Time

by Neil de Grasse Tyson

> *Science consists in discovering the frame and operations of Nature, and reducing them, as far as may be, to general rules or laws—establishing these rules by observations and experiments, and thence deducing the causes and effects of things.*
>
> Sir Isaac Newton
> *Principia 1687*

In scientific inquiry, the answer to one simple question often fortuitously explains the answers to many others; it may even answer questions that have yet to be conceived. Powerful ideas also unify concepts or phenomena that were previously thought to be unrelated. For example, Sir Isaac Newton identified a falling apple and Earth's orbiting moon as different effects of a single law of universal gravitation represented by a simple equation. (The falling apple did not actually hit Sir Isaac on the head. He saw it fall from afar.)

Newton's famous equation is a recipe to compute the force of gravity between any two objects in the universe. A basic application of the equation shows that the force of gravity is greatest where an object is nearest another object and least at the point where it is farthest. Earth's gravity, for example, is slightly stronger at your feet than at your head.

The differential is small, so don't blame your lightheadedness on it. Earth pulls on your feet with a force that is less than one ten-thousandth of one percent stronger than that at your head. This simple difference in gravity, officially known as the tidal force, is felt by all objects as they are pulled by the gravity of all other objects in the universe.

Tidal forces are the cause of an array of cosmic phenomena that otherwise seem to have nothing to do with one another. Some of my favorites: the daily rise and fall of Earth's oceanic tides; Earth's gradually slowing rotation rate, which is making our days longer and longer; the Moon's slow spiral away from Earth; the Moon showing only one face toward Earth at all times; Pluto and its lone moon, Charon, showing each other only one face during their mutual orbit; the geological (or is it Iological?) activity of Io, one of Jupiter's moons; the breaking apart of Comet Shoemaker Levy-9 in its close encounter with Jupiter; the long tails of colliding galaxies; and the spectacularly gory death to which you would succumb if you approached the center of a black hole (see last month's Universe essay, "Death by Black Hole").

Tidal forces are strongly dependent on distance. A mild increase in distance between two objects can make a large difference in the strength of the tidal force. For example, if the Moon were just twice its current distance from us, then its tidal force on Earth would decrease by a factor of eight. (The Sun is so far away that in spite of its generally strong gravity, its tidal force on Earth amounts to less than half that of the Moon's.) At its current average distance of 240,000 miles from Earth, the Moon creates sizable atmospheric, oceanic, and crustal tides that stretch toward it. Among the three, the oceans respond most visibly. As the solid Earth rotates, however, the continental shelves are constantly trying to push forward 1.5 quintillion tons of bulging ocean water. As a consequence, the oceanic bulge is not aligned with the Moon but is always found slightly ahead of it.

Rotating within the bulge, the Earth suffers enormous friction as the sloshing oceanic water meets the continental shelves and shores. (Embarrassingly, annual consumption of electrical energy by all quarter-billion residents of the United States is only slightly less than the annual tidal energy lost by such friction.) Earth therefore rotates more slowly, and our day gets longer: every century, the duration of the average day increases by one five-hundredth of a second. At this rate, it would take five hundred centuries to grow the day by one second. Meanwhile, fractions of seconds accumulate from day to day. Don't look for this tally in the newspapers next to the table of coastal tides—it's not there. But it ought to be because every few years we must adjust our time reckoning with "leap-seconds" at the end of June or December. (Don't laugh, but I have attended leap-second parties, where we counted down from 61 beginning at 11:59 P.M.) The need for leap seconds will accelerate over time, so that in five hundred centuries, when every day is one second longer, leap seconds would be added daily.

The best evidence for the slowing down of Earth's rotation comes from detailed records of total solar eclipses that date back many centuries. If Earth's rotation rate was faster in the past, then a total solar eclipse as seen on Earth's surface would have been west of the spot where we might expect it to have occurred, which is precisely what the records show—the earliest recorded eclipses were shifted along Earth's surface by nearly a thousand miles.

As Earth's rotation slows, the gravity from its tidal bulge (which is angled slightly ahead of the orbiting Moon) acts in return as an energy pump. Like a playground swing that responds in rhythm to the pumping of your legs, the Moon slowly spirals into a larger orbit.

You want proof? In 1969, when the Apollo 11 astronauts visited the Moon's Sea of Tranquillity, they left behind (among other things) an array of "corner" reflectors designed to reflect light back in exactly the same direction from which it arrives. Starting shortly after the Moon landing and continuing today, high-powered lasers on Earth are beamed to the Moon, and the return signal is carefully timed. One can therefore compute the Moon's distance from Earth with unprecedented accuracy: with a twenty-five year base line of measurements, we know that the Moon is spiraling away from us at a rate of about two inches per century, just as predicted by tidal theory.

More proof? A fossil coral from the Devonian Period (350 million years ago) displays growth ridges cued to the rhythm of the full Moon. The corals accumulated these ridges at the rate of thirteen per year, so the lunar month must have been about a day and a half shorter than today's—just what you'd get if the Moon orbited closer to Earth in the past.

Earth's rotation will continue to slow down, and the Moon will continue to spiral away until the Earth day exactly equals the lunar month. At that time, one Earth rotation will last more than one thousand hours, which would require about four million leap seconds per day. No need to panic just yet. You have more than a trillion years to think about it.

Earth's tidal force upon the Moon completed its job long ago: the Moon's rotation has slowed so that its period of rotation exactly equals its period of revolution around Earth—it becomes "tidally locked." In other words, as seen from Earth, the Moon has a permanent near side and far side, and when viewed from the near side of the Moon, Earth never sets. At one time or another during a lunar month, however, all sides of the Moon receive sunlight. So contrary to common parlance, folklore, and the title of Pink Floyd's best-selling rock album, there is not now, nor was there ever, a "dark side" of the Moon.

> Contrary to the title of Pink Floyd's best-selling rock album, there is not now, nor has there ever been, a "dark side" of the Moon.

When Earth's rotation slows down to exactly match the orbital period of the Moon, then Earth will no longer be rotating within its Moon-induced oceanic bulge and the Earth-Moon system will have achieved a "double tidal lock." Double tidal locks are energetically favorable (like a ball coming to rest at the bottom of a hill) and are thus common in the universe. Pluto and Charon achieved one in their 6.4-day cosmic waltz. A related phenomenon will unfold before your eyes if you spin a mobile of the type created by American sculptor Alexander Calder. If any pair of the dangling parts are elongated, then they will eventually align with each other and, in effect, become tidally locked, although energy, not gravity, is the active ingredient here.

Earth and Pluto are unusual in the solar system because their moons orbit nearby and are relatively large. One could accurately describe the Earth-Moon and Pluto-Charon systems as double planets. These configurations and others, such as closely orbiting double star systems, lead to strong tidal forces and to double tidal locks.

After learning about the general strength and prevalence of lunar tides, students often ask me whether the Moon's tidal forces can affect human behavior. Yes, provided you have a very, very big head. If your brain were, say, 8,000 miles in diameter (the size of Earth), then the Moon's tidal forces would indeed give you an oblong-shaped cranium and induce untold derangements on your mental faculties. For normal *Homo sapiens,* however, the difference in the Moon's gravity from one side of the head to the other is immeasurably small. The weight of an understuffed down pillow imparts a squeezing force that is more than seven trillion times larger than the Moon's tidal force on your head—a fact not shared with you by those who write about werewolves and other moon-based dysfunctional behavior.

No discussion about tidal forces is complete without giving due respect to the planet Jupiter. Packing more mass than all the other planets combined, Jupiter has tidally locked all of its inner satellites, including Galileo's famous four: Io, Europa, Ganymede, and Callisto. To be tidally locked should mean that no energy is being lost to friction, but a careful study of Io shows that the exact shape of its orbit is slightly affected by the combined gravity of the other nearby satellites. In other words, its distance from Jupiter varies, which also means it speeds up as it orbits closer and slows down as it orbits farther. Now consider that Io's rotation rate exactly equals the time it takes for one complete trip around Jupiter and you have a satellite whose face appears to jiggle to and fro while its Jupiter-facing tidal bulge continually flexes the satellite.

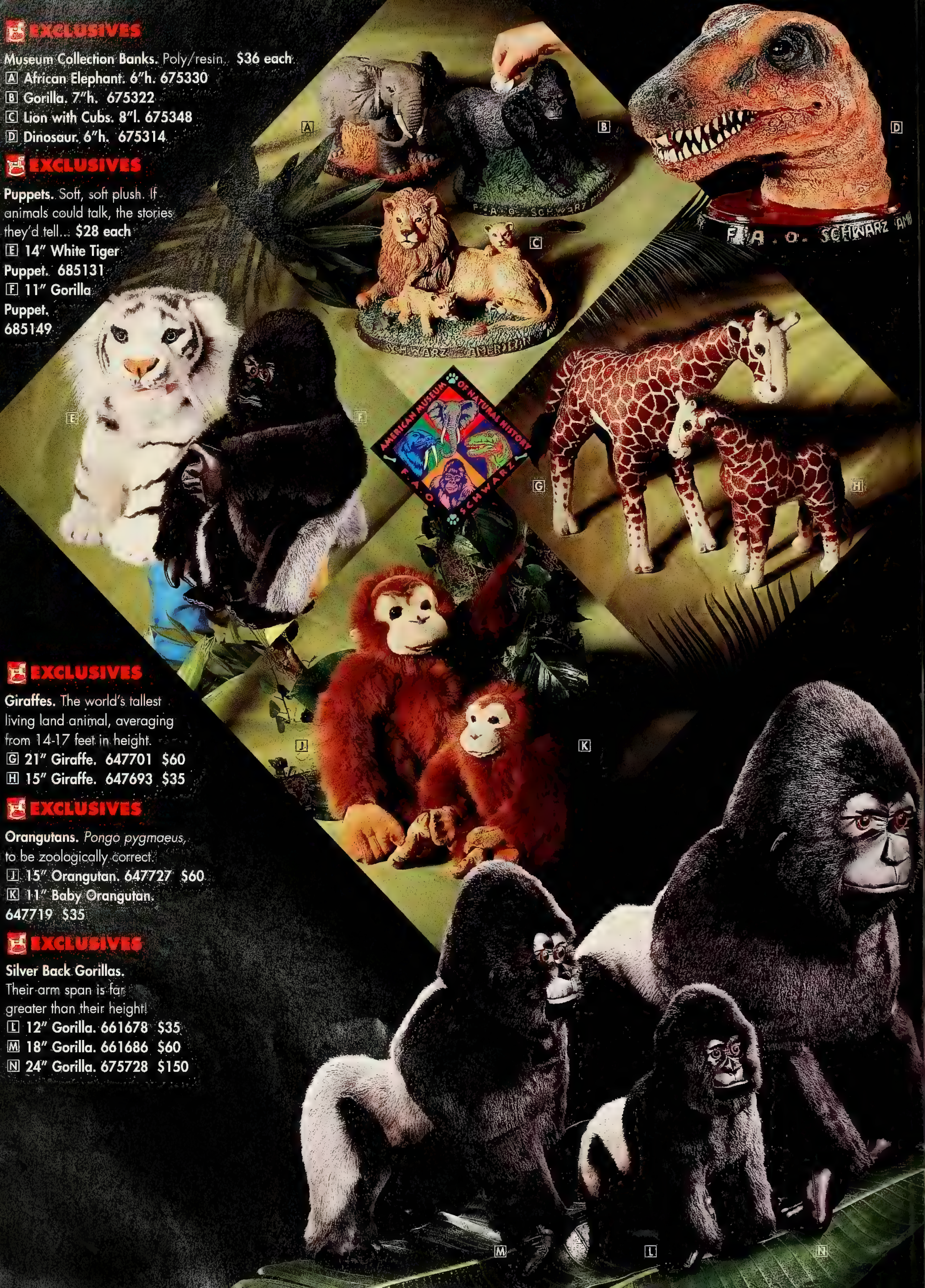
When the Moon flexes Earth's oceans, they simply slosh back and forth. But when a Jupiter-sized tidal force acts upon a nearby solid body, then varying internal stress can become a prodigious source of friction and, therefore, of heat. In one of the more timely and impressive predictions in the history of space probes, Stanton Peale, of the University of California, and collaborators published a paper in 1979 entitled, "Melting of Io by Tidal Dissipation." Later that year, images sent by the *Voyager 1* spacecraft revealed extraordinary volcanic activity, complete with calderas and gaseous plumes.

Jupiter's tidal forces also wreak havoc on comets that wander too close. The late Comet Shoemaker-Levy 9 was minding its own business in orbit around the Sun when, during one of its trips, it came too close to Jupiter and was captured into a greatly elongated orbit. In 1992 the comet came so close to Jupiter that tidal forces ripped it into dozens of pieces. On the next pass, in July 1994, none of the two dozen comet parts cleared the cloud tops. As if to exact a kamikaze-style revenge, they all blazed into Jupiter's thick and colorful atmosphere at a speed of nearly forty miles per second and exploded with the equivalent energy of hundreds of billions of tons of TNT.

On a cosmic scale, the tidal forces between two colliding galaxies can create spectacular photo opportunities: When two galaxies collide, they can be reshaped and ripped apart. Telltale evidence includes the long, often distorted "tidal tails" of stars that are created during the encounter. One such wreck is a pair of galaxies, NGC4038 and NGC4039, fifty million light-years away. They are nicknamed Antennae, but they really look like two procreating mice.

The next time you find yourself on a beach watching the tide come in, remember that the "frame and operations of Nature" extend to the farthest galaxies, and that the "causes and effects of things" are, fortunately, remarkably few in number.

Neil de Grasse Tyson is an astrophysicist with a joint appointment at the Hayden Planetarium and Princeton University.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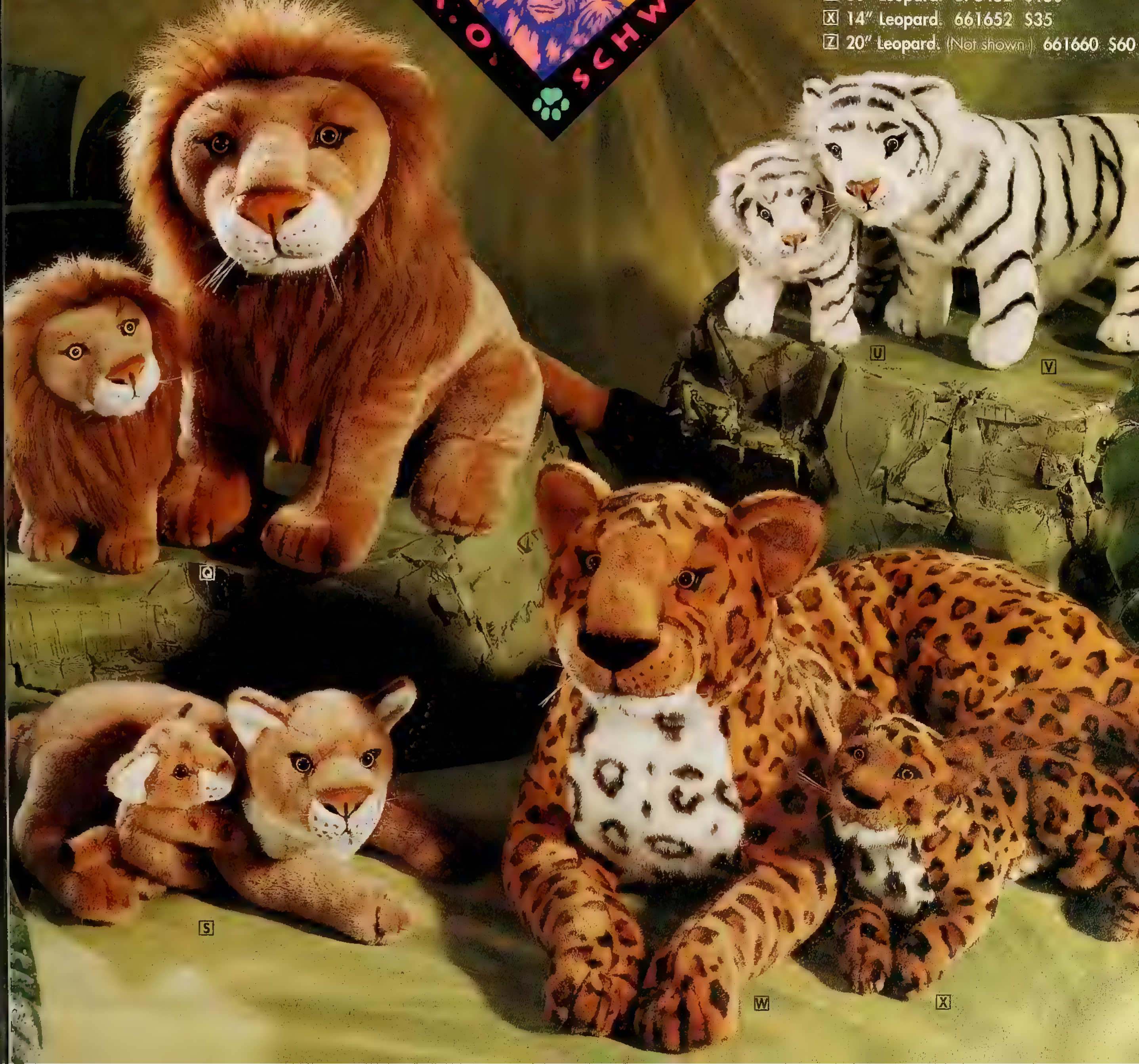


Pathogens New and Old

by Pascal James Imperato

Emerging pathogens are currently the subject of best-selling books, a Hollywood film, front-page news stories, and lengthy, prime-time television news commentaries. Often deadly, poorly understood, and increasing in numbers, pathogens both frighten and fascinate. Yet in the rush to chronicle the terrible epidemics they cause, little is said of the factors that lead to their emergence. These often defy facile scientific solutions, such as vaccines and drugs, because they are social, behavioral, political, and technical in character.

As we alter our relationships with the natural world, delicate balances between pathogenic organisms, humans, and the environment are disrupted. As a result, we come into contact with new viruses, transport old ones to new locations, and increase our vulnerability by tampering with the air we breathe and the food we eat.

Hives of Sickness focuses on past epidemics in New York City. The book's title is derived from the phrase "hives of sickness and vice" used in an 1865 report, *Sanitary Conditions of the City,* to describe "the high brick blocks and closely-packed houses" of a slum area of the city. The metaphor is particularly appropriate because it links epidemics with two powerful determinants—the physical environment and social conditions.

The first of the book's three sections, "Breeding Grounds for Disease," addresses the connection between the prosperity of one class and the abject poverty of another. Many held the poor collectively responsible for slum conditions and epidemics because of alleged racial deficiencies, superstitious beliefs, and unhygienic habits. In the 1916 polio epidemic, for example, Italian newcomers were blamed, even though the epidemiologic evidence clearly showed that the prevalence of polio was just as high among the middle class. The Irish had once been accused of causing cholera outbreaks, and the Jews, tuberculosis. Such stigmatization persists. In the early 1980s, the federal Centers for Disease Control (CDC) classified Haitians as a high-risk group for AIDS. By the time the CDC dropped them from its high-risk classification, thousands of Haitians had lost jobs, housing, and educational opportunities.

HIVES OF SICKNESS: PUBLIC HEALTH AND EPIDEMICS IN NEW YORK CITY, edited by David Rosner. *Rutgers University Press, $35; 223 pp., illus.*

KEEP OFF THE STREET

Polio epidemic, New York 1916. From A SUMMER PLAGUE: POLIO AND ITS SURVIVORS, by Tony Gould. *Yale University Press, $30.*

Range/Bettmann; UPI

In the book's second section, "When Epidemic Strikes," three twentieth-century epidemics in New York City—smallpox, polio, and AIDS—are insightfully described from the point of view of prevailing "social and scientific assumptions." The third section of the book, "The City Responds," describes how New York City has dealt with epidemics.

Hives of Sickness is an instructive history. The sheer growth in our numbers has given rise to migration and human encroachment on the once wild and rural refuges for many pathogens. Transported from a forested environment where it had achieved some measure of equilibrium with its hosts, the Ebola virus recently proved deadly in an urban hospital in Kikwit, Zaire. In large part, its spread was due to the absence of basic infection-control measures that are routine in the United States and Europe.

These historical accounts make for absorbing reading. The stories of scientific reason prevailing over prejudice, and the discussions of how diverse environments shape epidemics, bring the lessons of the past to bear on the present.

Pascal James Imperato is Distinguished Service Professor and chair of the Department of Preventive Medicine and Community Health, State University of New York, Health Science Center, Brooklyn.

A Guide to Winter Reading

War of the Worlds: Cyberspace and the High-Tech Assault on Reality, by Mark Slouka. *Basic Books, $20.*

Slouka, a lecturer in English and popular culture at the University of California at San Diego, cautions against a wholesale plunge into cyberspace, maintaining that it fosters a collectivist mentality and discourages individual thinking.

Nature's Numbers: The Unreal Reality of Mathematics, by Ian Stewart. *Basic Books, $20.*

Ian Stewart, a prolific popularizer of science, applies mathematics to the understanding of such regularities in nature as the underlying biological patterns of tigers' stripes, the atomic structure of ice crystals, and the processes of ocean waves.

Bird Brains: The Intelligence of Crows, Ravens, Magpies and Jays, by Candace Savage. *Sierra Club Books, $25.*

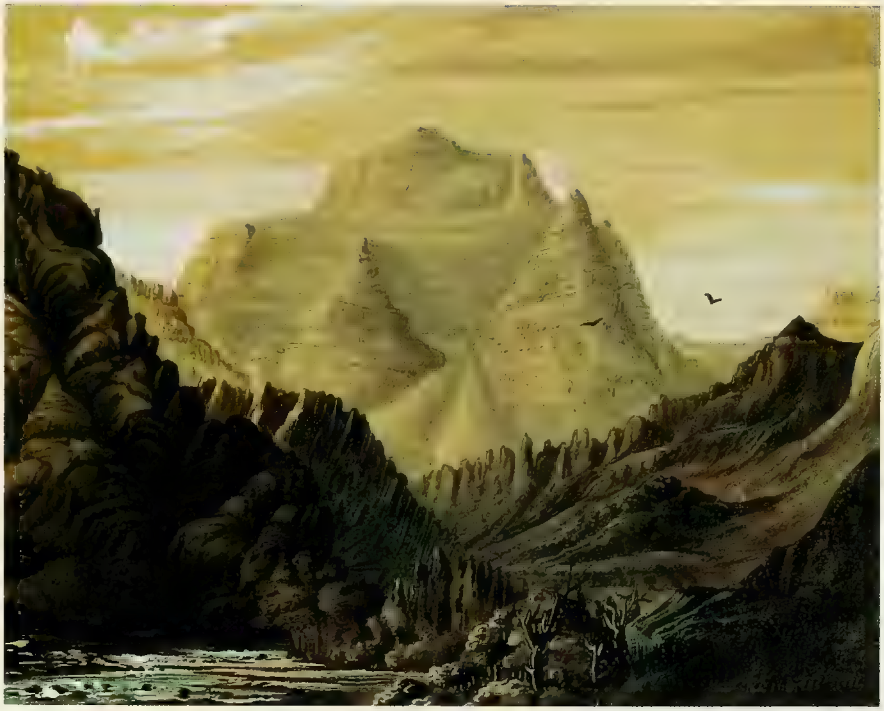
The corvids, a bird family that includes crows, ravens, and their relatives, express a range of "intelligent" behavior, such as ganging up, playing, showing off, weighing options, and grieving. The book features more than sixty photographs of these avian cognoscenti, and Savage makes her case, drawing from the work of such notable corvid-observing scientists as Bernd Heinrich, Konrad Lorenz, and Russell Balda.

Alone: The Classic Polar Adventure, by Admiral Richard E. Byrd; afterword by David G. Campbell. *Kodansha Globe, $15* (first published in 1938).

In 1934, Byrd's expedition to Antarctica to record weather data and "to taste peace and quiet long enough to know how good they really are" turned into a struggle for survival. When it was published in 1938, Byrd's harrowing, first-person narrative was an instant bestseller.

Schneider on Schneider: The Conversion of the Jews and Other Anthropological Stories, by David M. Schneider as told to Richard Handler; edited and with an introduction by Richard Handler. *Duke University Press, $44.95.*

What began as an interview for a scholarly journal turned into a book-length memoir in Q. and A. form. Schneider, whose career involved fieldwork on the Pacific island of Yap, as well as studies of contemporary American kinship, gives an anecdotal, humorous, and informed account of the state of post-World War II anthropology.



Watercolor of the 1858 Ives Expedition up the Colorado River. From Wild River, Timeless Canyons: Balduin Möllhausen's Watercolors of the Colorado, by Ben W. Huseman. *Amon Carter Museum/University of Arizona Press, $70.*

Amon Carter Museum, Fort Worth

Ancestral Passions: The Leakey Family and the Quest for Humankind's Beginnings, by Virginia Morell. *Simon and Schuster, $30.*

Anthropologist Louis Leakey, born to Anglican missionaries in Kenya, his archeologist-artist wife, Mary, and their son Richard are famous for shaping the modern study of human evolution in Africa. Morell presents a well-documented portrait of a brilliant family at war with itself. Given the Leakeys' involvement in science, politics, world culture, and the history of Kenya, this true story has the feel of a full-blown epic novel (*see* "Leakey for President?" page 8).

Savages, by Joe Kane. *Alfred A. Knopf, $25.*

Kane, author of *Running the Amazon,* gives a firsthand account of how the Huaorani, a nation of 1,300 nomadic people residing in the huge, oil-rich area of Amazonian Ecuador, have coped with waves of intrusion and exploitation, whether by missionaries, oil companies, environmentalists, or government bureaucrats. This tale of cultural destruction is deeply moving, yet laced with humor and irony.

The Neandertal Enigma: Solving the Mystery of Modern Human Origins, by James Shreeve. *William Morrow and Company, Inc., $25.*

About 35,000 years ago, an intelligent, strong human species, the Neandertals, disappeared. Were they our ancestors, our cousins, or our competitors? Did they peacefully coexist with our competitors? Shreeve, a science writer and editor, attempts to solve this anthropological mystery.

SECRETS OF THE DARK CHAMBER: THE ART OF THE AMERICAN DAGUERREOTYPE, by Merry A. Foresta and John Wood. *Smithsonian Institution Press, $55.*

From 1839 through the end of the Civil War, daguerreotypes were all the rage of America. The 150 daguerreotypes presented here are from the National Museum of American Art's current exhibition. Subjects range from portraits to rural and urban landscapes to industrial subjects and to domestic scenes by the great daguerreotypists of the day, William and Frederick Langenhein, Thomas M. Easterly, James Presley Ball, Albert Southworth, and Josiah Hawes.

Moss campion, Northwest Territories. From POLES APART: PARALLEL VISIONS OF THE ARCTIC AND ANTARCTIC, by Galen Rowell. *University of California Press, $39.95.*

Galen Rowell

CHINA POP: HOW SOAP OPERAS, TABLOIDS, AND BESTSELLERS ARE TRANSFORMING A CULTURE, by Jianying Zha. *The New Press, $21.95.*

China has rapidly evolved a modern pop culture complete with movies, novels, media figures, and even a soap opera called *Yearnings*. Zha, born and raised in Beijing and now a scholar at the University of Chicago's Center for Transcultural Studies, offers vivid, firsthand perspectives on these developments.

HAITI, HISTORY, AND THE GODS, by Joan Dayan. *University of California Press, $35.*

Voodoo evolved alongside the transformation of the French colony of Saint-Domingue into the Republic of Haiti, and the liberation of its people from slavery. Joan Dayan, professor of English at the University of Arizona, traces facts that are known and those that are suppressed in Haitian history, and reconstructs a memorable portrait of the country from historical, legal, and religious texts as well as from memoirs, letters, and literary fiction.

POQUOSIN: A STUDY OF RURAL LANDSCAPE AND SOCIETY, by Jack Temple Kirby. *The University of North Carolina Press, $39.95.*

The Algonquian Indians called the low country between the James River in Virginia and Albemarle Sound in North Carolina *Poquosin,* meaning "swamp-on-a-hill." Over more than two centuries, the inhabitants of this vast wetland have had an ever-changing relationship with their environment. Today, controversy rages over a proposed four-mile pipeline to Lake Gaston.

LANGUAGE AND HUMAN BEHAVIOR, by Derek Bickerton. *University of Washington Press, $24.95.*

Syntax—the organization of word groups into a sentence—is what distinguishes human use of language from that of other animals. Bickerton, a professor of linguistics at the University of Hawaii at Manoa, argues that thinking crucially involves language and explores its evolutionary basis. Only humans can practice both on-line thinking (response to external objects) and off-line thinking (response to internal representations of external objects), says Bickerton, who debates alternative theories of scientists such as Steven Pinker, Patricia Churchland, Michael Gazzaniga, and Roger Penrose.

THE ORCHARD: A MEMOIR, by Adele Crockett Robertson. *Henry Holt and Company, $20.*

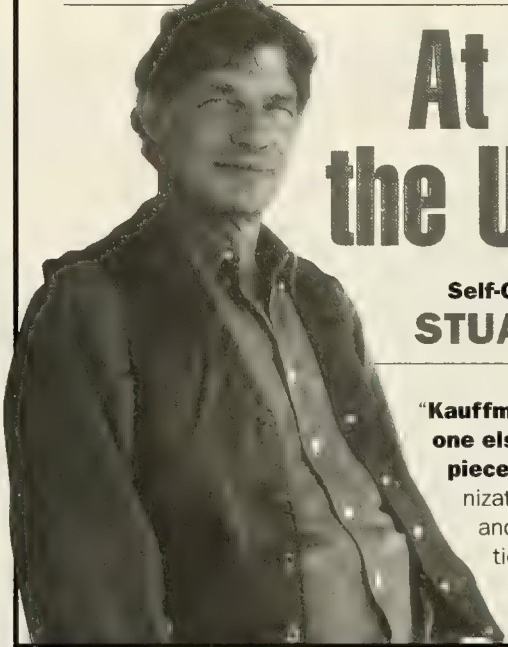
In the midst of the Depression, after graduating from Radcliffe and working for a time in Boston, Adele Robertson moved back to her family's abandoned farm outside of Ipswich, Massachusetts, to revive its old orchard. After Robertson died, her daughter discovered and published the manuscript her mother had written about running the operation more than sixty years ago.

BOMBARDIER BEETLES AND FEVER TREES: A CLOSE-UP LOOK AT CHEMICAL WARFARE AND SIGNALS IN ANIMALS AND PLANTS, by William Agosta. *Addison-Wesley Publishing Company, $25.*

When a bombardier beetle is attacked, it responds with a spurt of a toxic, burning liquid—quinone—accompanied by an audible pop. From the flexible tip of its abdomen, it can fire accurately up to twenty times in four minutes. Agosta, professor at, and head of, Rockefeller University's Organic Chemistry Laboratory, explores the subject of nature's chemicals and the living creatures that synthesize them.

HUBBLE VISION: ASTRONOMY WITH THE HUBBLE SPACE TELESCOPE, by Carolyn Collins Petersen and John C. Brandt. *Cambridge University Press, $39.95.*

The Hubble Space Telescope (HST), which was successfully repaired in space in December 1993, can peer ten times farther into the universe than a telescope on Earth. Using some of the most dramatic images from the HST, University of Colorado astronomers Petersen and Brandt discuss the information it is beaming back to Earth about such things as white dwarf stars, quasars, binary stars, and galaxies with black holes at their centers. They also discuss how HST is constructed and how it operates. ☐



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Blood Relations

A geneticist studies the family ties of whales—and ponders the values of an ancient whaling culture

by Bill Amos

Our tiny plane touched down at the Faeroe Islands' only airport, Vágar. En route, I had enjoyed a good view of the islands' treeless, grassy fells, deep fiords, and staggering cliffs dropping as much as 2,500 feet into the sea. A long, winding bus journey and a ferry crossing brought me to the main island of Eysturoy. Finally, I arrived in Tórshavn, the capital and home to a third of the islands' 47,000 people. Here I joined several other scientists based in a small wooden house in the heart of the city, where we were to live on twenty-four-hour standby, waiting for our beepers to let us know that a whale drive—known locally as a *grind*—had begun.

The Faeroese harvest pilot whales but do not pursue the animals on oceangoing ships. Instead, they use small boats to corral or herd whales that have begun to approach the shore, taking advantage of the species' proclivity for mass strandings—a phenomenon wherein whole pods of the whales swim onto a beach and perish. (One notorious pilot whale stranding site is Cape Cod, Massachusetts.) In years past, other coastal peoples learned to hunt pilot whales in this fashion, but today such "drive fishing" survives only on the Faeroes, a remote archipelago between Norway and Iceland.

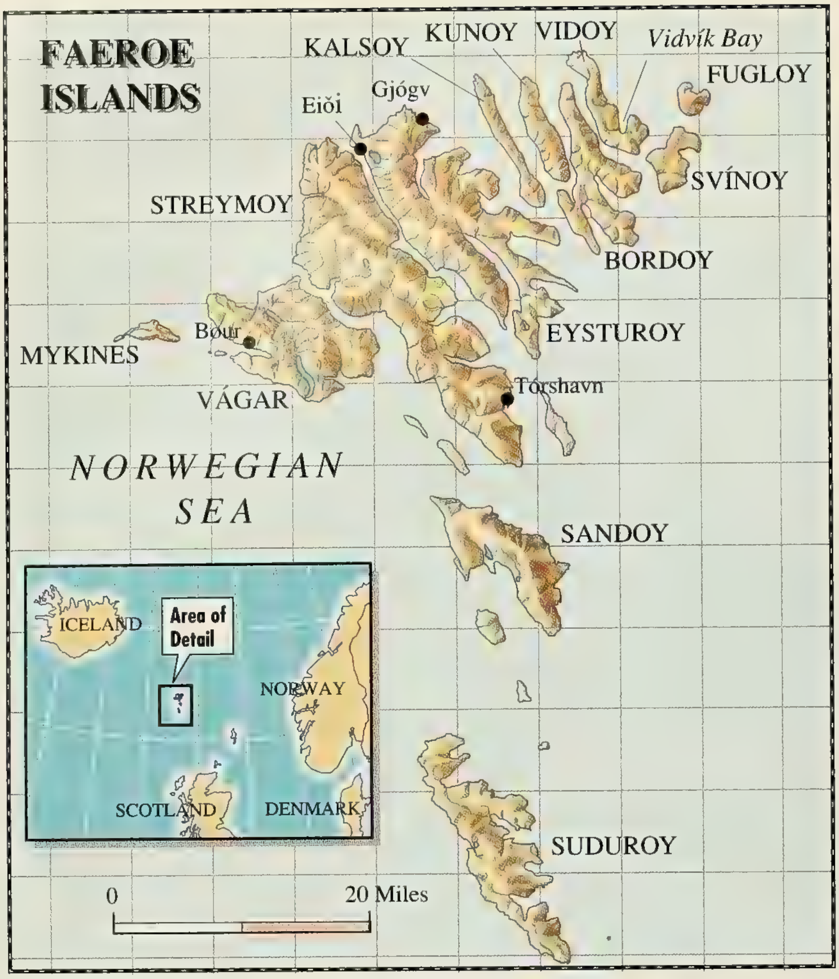
For the last ten years, conservation groups have increasingly pressured the Faeroese to stop killing whales, urging boycotts of local fish products and staging demonstrations in which activists in inflatable dinghies have attempted to disrupt the whale drive. In response, the Faeroese government funded a two-year research program, inviting foreign scientists to visit the islands to study the *grind* and assess its effect on the pilot whale. My role in the study was to obtain samples of whale skin for genetic analysis. I would then try to ascertain the relationships between individual animals in the pod. Other scientists were looking at reproductive physiology, pollutant levels, body condition, parasite burdens, and hormone levels. The Faeroese themselves orchestrated the operation and collected basic data on the whales, such as

Given to mass strandings, pilot whales can be herded to shore by hunters in small boats.

The aftermath of a pilot whale hunt on Eysturoy Island

Tony Martin; Oxford Scientific Films

Joe LeMonnier

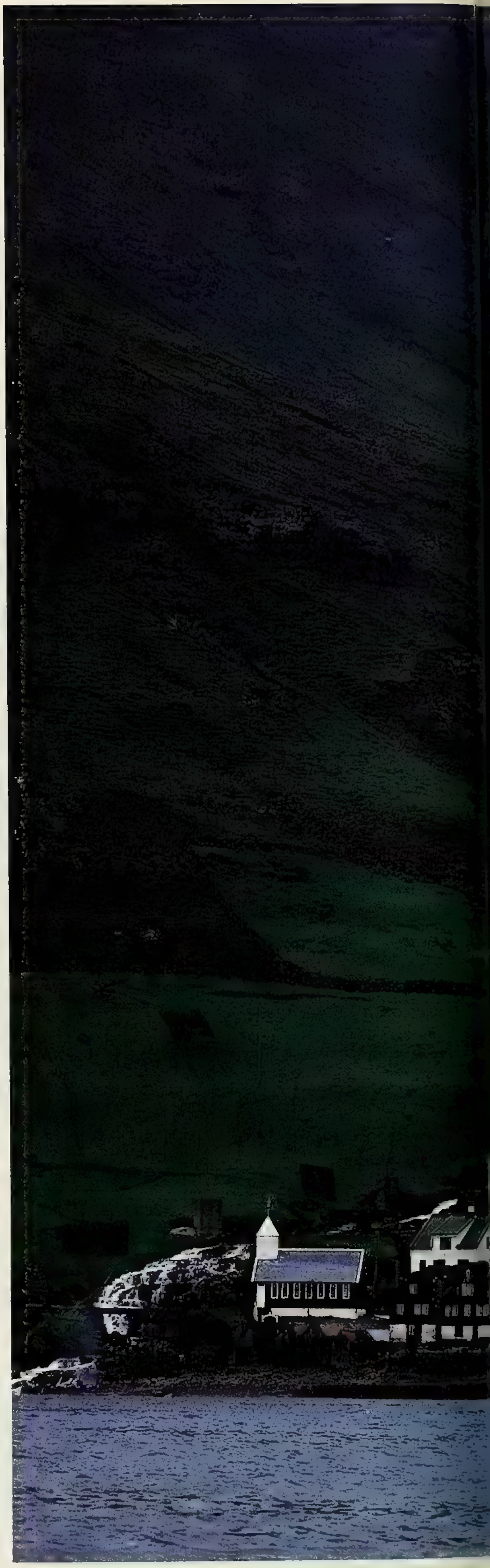

FAEROE ISLANDS
KALSOY
KUNOY
VIDOY
Vidvík Bay
FUGLOY
Gjógv
Eiði
SVÍNOY
STREYMOY
BORDOY
EYSTUROY
Bøur
MYKINES
Tórshavn
VÁGAR
NORWEGIAN SEA
SANDOY
ICELAND
Area of Detail
NORWAY
SCOTLAND
DENMARK
SUDUROY
0
20 Miles

About halfway between Norway and Iceland, the Faeroe Islands have home rule, but are part of the kingdom of Denmark.

age (by counting growth rings in the teeth), length, weight, and sex.

To say that I had misgivings about going on a whale drive would be an understatement. As a geneticist who previously worked on fruit flies, I had no experience as a whale biologist. More important, I had watched the antiwhaling groups' videotapes of the hunt and had found them deeply disturbing. Nonetheless, I accepted the assignment, and soon after I arrived on the Faeroes, the first call came. From the perspective of the locals, it could not have come at a worse time—during Olafsøk, the annual festival of Saint Olaf, when the whole capital parties, and when alcohol, despite its exorbitant price, is consumed in vast quantities around the clock. Our beepers sounded after midnight, causing a wave of slurred anger among our Faeroese friends.

Bryan and Cherry Alexander



Traditional laws require anyone who sees whales to initiate an attempt to catch them, but nowadays many accept that during Olafsøk it is excusable, even preferable, to turn a blind eye. Nevertheless, once someone has raised the alarm, the wheels are set in motion and people comply. Thus it was that we set off, our blood circulating a heady mixture of adrenaline, whiskey, and as much black coffee as we could gulp on our way to the beach. However, in pitch dark, with too few boats, and these manned by the reluctant and the inebriated, the drive was a lost cause, and the whales made good their escape.

The first "successful" hunt I witnessed took

Dave Currey; Environmental Investigation Agency

Isolated on the west coast of Vágar, the village of Bøur, left, is accessible only by boat. Above: When a catch is weighed, the sharing-out process begins.

In years past, lookouts were stationed on mountains to spot passing whales.

place a week or so later, at a tiny little village called Bøur, a handful of houses clustered around a grass-roofed church. With unexpected abruptness, the whales arrived at the beach. Waiting villagers, armed with hooks, knives, and ropes, ran chest-deep into the freezing Atlantic waters to begin the kill. In shocked awe, I followed the rest of the scientific team into the melee, desperately trying to remember the sampling plan, fighting to keep my balance on the slippery rocks, and doing my best not to just stare stupidly at the unfolding spectacle. It all ended suddenly, a mere seven minutes after it had started, with fifty-four animals dead in a sea now crimson with their blood. My baptism into whale biology was over.

After a kill, every local family collects a share of the whale meat.

After the kill, the bodies of the whales were towed to a nearby harbor for inspection by the local sheriff. At this point every whale is given two numbers, one for identification and the other, the *skinn* number, to describe its size. One *skinn* is equal to about 110 pounds of meat and 60 pounds of blubber. A time is then set for meat distribution, when one member of every local family will come to collect a share. Drives usually take place in the early morning and collections in the evening, giving us scientists several hours to take a full set of samples.

The pilot whale is a medium-size species, reaching twenty feet in males and sixteen feet in females, and more closely related to dolphins than to the great whales. The species gets its name from its supposed ability to pilot ships toward shoals of fish. Our knowledge of pilot whale biology, as of most cetaceans, is rather poor. There are two species, the long-finned and the short-finned, distributed widely throughout the world's oceans. The long-fin, my study animal, prefers the cooler waters of the Southern Hemisphere and the North Atlantic; the short-fin prefers warmer regions. The pilot whale is extremely social, usually seen in groups numbering between 50 and 250 but occasionally in aggregations of up to 2,000. The groups range widely in pursuit of shoals of their preferred food, squid.

Before 1900, the Faeroese, like many northern coastal peoples, relied on the sea for the greater part of their diet: fish, seabirds such as puffins and fulmars, and marine mammals were the main sources of protein. Other flesh food was provided by small, hardy sheep, a primitive breed that picks a meager living from the impoverished vegetation of the hills. The only vegetables that can cope with the Faeroes' short, cold, windy growing season are a few bulletlike potatoes, of which the islanders are surprisingly proud, and some rhubarb. A mass stranding or a kill of pilot whales was therefore a nutritional windfall, because of both the quantity of whale meat and the vitamins in its blubber. In hard times, a successful whale hunt could literally make the difference between life and death. Consequently, the *grind* assumed a central role in Faeroese culture. The local records are a measure of its importance; all pilot whale catches have been carefully documented since 1600.

Until the turn of this century, lookouts were stationed on the tops of mountains to spot passing whales. News of a sighting would then be carried to local villagers by a complex system of runners, beacons, and boats. Upon receipt of the message, known as a *grindabod,* people in the nearby villages were expected to immediately cease what they were doing and help land the whales. In celebration of a kill, dances would be held, at which people would recite long passages from the oral history of the Faeroes.

These days, ferries and fishing boats eliminate the need for hilltop observers and the *grindabod* is carried by radio waves, but in most other aspects the *grind* has changed little. Even sudden wealth, brought by a commercial fishing boom in the early 1970s, has had little effect. No whale meat is exported to other countries, and most is eaten within a few miles of where it was landed. Thus, islanders say the whale hunt is not commercial. But because pilot whales and other small cetaceans are not regulated by the International Whaling Commission (IWC)—their inclusion is now being sought by many member nations—the *grind* is neither classified as an allowable, "aboriginal" industry nor banned under the IWC's worldwide moratorium on whale hunting.

During my three months in the Faeroes, I was alerted to fifteen drives, but because the whales are herded very quickly, I arrived in time to see the kill only twice. (Only those who live in the nearest villages take part in the drives. Outside observers may have to travel by car and boat for many hours. Since the kills I did see were rapid, I wonder whether uninvited videotapers of the event wouldn't be likely to get footage only of the very worst kills, where the drive has been long, and the whales especially stressed.)

On my return to my laboratory in Cambridge, I was faced with box after box of frozen samples, some 3,500 in all, as well as reams of written background on each animal. The general data on the pods revealed that they contained males and females of all ages, including newborns. It fell to me to sort out their relationships. Not all the pods had been sampled completely; sometimes we had run out of time. In view of this, I decided to

Boats in Tórshavn harbor
José Azel; AURORA

concentrate on two large pods with a complete set of samples and a handful of other, smaller pods. As the genetic analysis progressed, I felt more and more like a detective following a trail of clues, each extra little bit of information firming up the picture that was emerging.

I knew that some animals must be swimming with their mothers, but how many? By matching up genes, I found that not only were almost all the youngest whales (up to five years old) with their mothers, but so were more than a third of the fully adult animals, aged twenty years and older. Allowing for natural mortality, this suggested that most whales remain with their mothers for their entire lives.

Were fathers of the young also swimming with the pod? To find out, I used DNA fingerprinting, a technique in which highly variable genetic characters are seen as patterns of bands, appearing rather like a supermarket bar code. Since DNA is inherited, each individual's bar code is made up of roughly equal numbers of bands from each parent. If we place the bar code fingerprint of a baby whale next to that of its mother, it is easy to identify the bands that they share. More important, bands that appear in the baby but not in the mother must have come from the father.

The answer to my question was clear. None of the adult males in the sampled pods had fathered the young—not even the very small fetuses, less than a month in gestational age. Had the fathers high-tailed it out of the area once the drive had begun? I doubted it, because the Faeroese report that escapees from a hunt are very rare. (They also have a gruesome saying: "The whales always return to the blood," meaning that when whales do break away during the kill, they normally circle the bay and ultimately rejoin the rest of the pod.) Thus, it seemed likely that matings take place outside of the group, during relatively brief encounters between the future parents.

Are the pods assemblages of mothers with young or are they single families, as their amazing cohesion suggests? The first strong evidence that a whole pod was closely related came when I was still in the Faeroes, from a pod of seventeen whales landed at Vidvík, in the very north of the islands. As we motored toward the coast, high winds drove the rain almost horizontally; we arrived late and had to carry out our sampling under floodlights. Before long, several of us noticed that this pod was distinctive. Somebody mentioned that the dorsal fins appeared more hooked than usual; someone else thought the foreheads were more bulbous. I was trying to collect teeth to determine the animals' ages. Time and again, I put my fingers into a mouth and regretted it—the teeth were razor sharp, unlike the blunt, peglike teeth I had sampled until then.

Barbara Todd; EarthViews

Mother and baby pilot whales swim together within larger social groups that may number in the hundreds.

A subsequent look at the Vidvík pod's DNA revealed subtle differences between these whales and others I'd tested. It was the same for other pods. Each had a distinctive genetic signature. In each case, the oldest females carried the strongest genetic signature of the entire group, but the striking genetic resemblance between adults of both sexes showed that males swimming with the pod were not just visitors but members of the same family.

The final piece in the genetic jigsaw puzzle was supplied by the pregnant adult females, of which there were some in every pod. In each case, I compared the genes of the mother with those of her fetus to deduce the father's contribution. By grouping fetuses of similar age, a pattern emerged. Although very few fetuses in a group seemed to share the same father, the paternal genes were nonetheless found to be similar, indicating that the fathers were related to one another. The best explanation is that in the breeding season, the males from one pod mate with females from another. Indeed, this idea is supported by the observation that the very largest aggregations of pilot whales, numbering thousands, are seen mainly at the times of year when mating is thought to occur. Perhaps these are the interpod orgies that my genetic data predict.

That pilot whale pods are composed of single, huge families comes as no real surprise, given the remarkable way in which they can be herded. What was unexpected was that neither males nor females disperse. Pilot whales, it appears, remain in the pod in which they were born for their entire lives. Such a social organization is extremely unusual in mammals. Yet orca whales, the pilot whales' closest relatives, also stay with their mother's pod (*see* "Family Fugues," by

Were the pods unrelated mothers with young? Or single, extended families, as their social cohesiveness suggested?

James D. Watt; The Waterhouse

The pilot whale's bulbous forehead, above, has earned it the common name "pothead." Right: Eiði, a coastal village on Eysturoy.

For the last ten years, conservation groups have increasingly pressured the Faeroese to stop killing whales.

John K. B. Ford, *Natural History,* March 1991).

The close family structure has its advantages: related whales will most likely compete less for food and defend one another more fiercely from predators. Males that try to live in other pods run the risk of being shunned, while those that stay home are guaranteed cooperation. The main downside is the disadvantages of inbreeding. But as long as opportunities to mate with other pods come regularly, this may not be an issue.

I am now working to construct complete family trees for my two biggest pilot whale pods and looking into ways of using genetics to find out more about how pods relate to one another. Nevertheless, I can't help but return, time and time again, to the kill itself and to the questions it raises. After witnessing my first kill at Bøur, I stood silent, not disgusted, simply in awe. I had seen the blood. I had seen the whales dying, yet the scene did not shock me in the same way as the videos had. These men were not monsters. They were doing what they had been brought up to do, what their forebears had done: bringing in a valuable supply of food.

Some islanders point out that several of the European countries most vocal in their criticism of the Faeroese whale hunt actually cause greater harm to the pilot whales—and the North Sea ecosystem—through industrial pollution. Indeed whales, being at the top of the food chain, are particularly vulnerable. High concentrations of toxic metals, such as mercury and cadmium, have already been found in pilot whale tissues (and the Faeroese have therefore been warned against eating whale liver.)

As for me, I was left confused. After my stay in the Faeroes, I found that I valued the local culture as much as I valued the whales. My profound belief that killing whales is wrong under any circumstances was shaken. □

José Azel; AURORA

OLIE
OSTER

Sounds of Light and Hope

In Egypt, a Western-style orchestra breaks more than one barrier

Text by Philip D. Schuyler • Photographs by Lori Grinker Contact Press Images

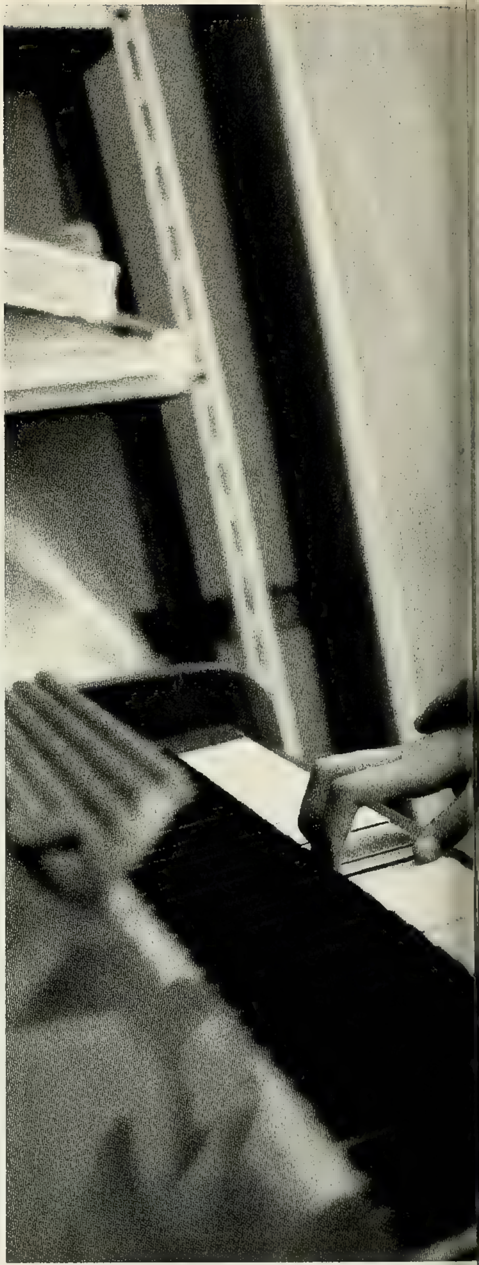
Early on a summer afternoon in Cairo, Egypt, the central hallway of Al-Nour wal Amal Association is quiet and empty. Shafts of sunlight, thickened slightly by dust, filter in from open doors on either side, leaving most of the corridor in dark shadows, a refuge from the blistering heat outside. It's Saturday, and almost time for a rehearsal of the association's orchestra. One by one, the musicians, women ranging in age from their midteens to late thirties, drift in from school or from outside jobs. Most of them wear a head scarf, or "veil," which has become a symbol of conservative Islam. For all its modesty, however, their clothing reflects considerable care in the cut of the long dresses, the matching of colors, and the drape of the scarves. Despite the dimness, many of the women wear sunglasses.

The excerpt from the Nutcracker Suite seems a bit out of place on a July afternoon in Cairo.

When they reach the end of the hallway, the women greet Sherifa Fathi, who has taken her place at a desk outside the rehearsal room. Sherifa teaches Arabic and music at the association's primary school and also prepares the parts for each new piece. During the summer she may work eight or more hours a day, taking dictation or copying music at her desk. As she reads, she runs her hands across the page from left to right, but as she writes, her right hand moves in the opposite direction. She is writing Braille, and like all who write Braille with a slate and stylus, she works in reverse, raising the pattern of dots by making small indentations on the back of the page. Al-Nour wal Amal ("Light and Hope") is a center for blind girls and women.

Two French horn players in the orchestra at Al-Nour wal Amal Association, a center for blind girls and women, relax during a break in rehearsal.

An older girl's head scarf, below, is a sign of Islamic devotion. A pianist, right, is guided during her lesson. Below right: A cellist uses Braille notation to learn her part.



In the rehearsal room, five fans (including one on top of the piano) mute the sounds of conversation and tuning but fail to dissipate the heat. At four o'clock exactly, Ahmed Abu el-Aid, the conductor, enters the room. A sighted man in his early sixties, he is often called the Maestro, and with his chiseled features and silver hair, he certainly looks the part. When the musicians are ready, Abu el-Aid announces the program for the day, beginning with a piece they've only just started rehearsing, Dvořák's Slavonic Dance in G minor.

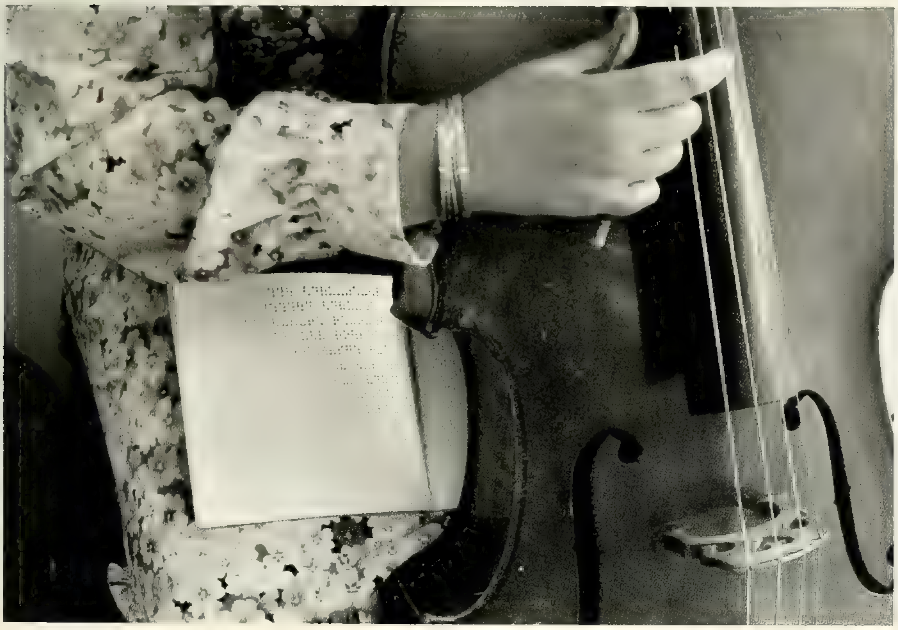
> **"If the blind had a special musical gift," the Maestro says, "we wouldn't need to test our students."**

Although most of the musicians can make out shadow and light, form and color—the association accepts applicants with partial sight as long as their corrected vision is no better than 20/400, the Egyptian standard for legal blindness—there is no point in leading the orchestra by waving hands or a baton. Instead the Maestro keeps time by slapping his lectern with the handle of a flyswatter. Then, once the music is well underway, he leaves the desk and walks through the orchestra, quietly coaching one section on their next entrance or gently correcting the position of a cellist's wrist and elbow.

Al-Nour wal Amal Orchestra is by no means the only group of blind musicians in the world. Indeed, there have been so many blind performers throughout history—from Homer, the legendary singer of epic poems, to Blind Lemon Jefferson, the blues player—that blindness and music are easily associated in the popular imagination. In a number of cultures, including those of Ukraine and Japan, the performance of certain kinds of religious song was formerly reserved for brotherhoods of blind performers. In Egypt, the chanting of the Qur'an was once practically the only way for a blind boy to earn a living, and today, Qasr al-Nour, the Cairo center for blind boys, has its own musical ensemble. The blind may be steered toward music simply because it is an activity they can pursue despite their disability. But many people—including a number of musicians at Al-Nour wal Amal—are convinced that an increased sensitivity to sound is a kind of compensation for the loss of sight.

"That's just a myth," insists the Maestro, who has been involved in music education for thirty years. "If the blind had a special musical gift," he continues, "we wouldn't need to test our students. But in my experience, the blind are just like the sighted. The only difference, really, is that the blind have more problems because a normal orchestra depends absolutely on sight. The musicians have to have one eye on the conductor and the other on the score. There are blind musicians—excellent musicians—all over the world; but they are soloists. We thought of bringing them together in an orchestra." In fact, the center has two orchestras, with about thirty-five members each. The principal ensemble, which includes some women who have been with the group since the beginning, performs in Egypt and abroad. The second, an ensemble of younger girls, was formed primarily as a training group but also performs for school audiences in Egypt.

When the Maestro uses the word "orchestra," he means, specifically, an ensem-



ble that plays what musicologists call Western European art music (or "classical music," if you're shopping at Tower Records). In Abu el-Aid's view, the ensemble at the blind boys' center does not qualify as an orchestra because the group plays Arab music exclusively. The melodies and rhythms of Arab music can be extremely subtle and complex, but the organization of the ensemble is relatively straightforward: all the instruments play essentially the same melody, and an accompanying drumbeat provides an audible point of reference. It is far more difficult, the Maestro maintains, to coordinate the chords and simultaneous melodies of Western harmony and counterpoint.

The Western European art music tradition has long been a part of the Cairo cultural scene. In the early nineteenth century, Muhammad Ali, who ruled from 1805 to 1848, instituted Western-style military marching bands as part of an effort to modernize his army. A successor, Ismail Pasha, built the Cairo Opera House, which opened with Verdi's *Rigoletto* in 1869 to celebrate the opening of the Suez Canal. Two years later it held the world première of the specially commissioned opera *Aida*. In this century, kings Fouad and Farouk were generous patrons of both European and Arab music. Since the overthrow of the monarchy in 1952, the governments of Gamal Abdel Nasser, and later Anwar el-Sadat and Hosni Mubarak, have also encouraged Western music through the founding of the Cairo Conservatoire and continued support of an opera company and a national orchestra.

Elements of Western music—especially the use of large orchestras with massed violins—have also influenced the style of Egyptian popular music since the beginning of this century. Nevertheless, according to Abu el-Aid, "Most of the listening public here doesn't know what classical music is. Brahms and Chopin don't have many listeners in Egypt." Egyptians do, however, like "clear, sweet melodies," and the Maestro indulges their taste (and his own) by planning mixed programs with selections of traditional Egyptian music, Western-style music by Egyptian composers, and, above all, European music from the late Romantic period.

The emphasis on the Western classical tradition helps insulate the orchestra from the criticism of conservative Muslims, some of whom maintain that music encourages licentious behavior. Although a few of the women at Al-Nour wal Amal are Christians, most are Muslims, and some of them were concerned enough about the propriety of their musical activity to seek the advice of a religious scholar. As Iman Fawzi, a bassist in the orchestra, explains, "Some people say that music is *haram*—forbidden—but the sheikh told us that we should consult our hearts and our feelings. He said that as long as the music doesn't make you dance or behave immodestly, it's all right." By these standards, the women judged the orchestra's music to be morally pure, which is ironic since much of their repertory was originally designed to inspire (or at least emulate) passion through dance: Strauss waltzes, excerpts from *Carmen*, Khachaturian's "Sabre Dance," Falla's "Fire Dance," and Saint-Saëns's "Bacchanale."

Overall, the choices reflect the Maestro's desire to develop a repertory that will be accessible and educational to Egyptian and foreign audiences alike. Within a few years of its formation in the late 1950s, Al-Nour wal Amal Orchestra had progressed enough to give public performances in Egypt—at the Opera House, the American University, and on television. And the quality of the orchestra improved dramatically when Abu el-Aid took over as conductor in 1984. In 1988, at the instigation of the Egyptian ambassador in Vienna, the orchestra made its first trip abroad, to Austria. This was followed by another tour of Austria the next year, and later by trips to Germany, England, Sweden, Spain, Morocco, Jordan, the Arabian Gulf states, Thailand, and Japan.

The orchestra is the most conspicuous project of the association, which was founded in 1954 by Istiqlal Radi, the daughter of a wealthy landowner. Radi's previous work with the Red Crescent, the equivalent of the Red Cross in the Muslim world, had made her aware of the problems of the blind in Egyptian society. Even today, according to Nafissette Khafagy, the director of social work at Al-Nour wal Amal, "a blind girl, especially in the countryside, has nothing to do but sit in the house, sit in the house, until she reaches a point where she is retarded—not mentally retarded, but socially retarded, culturally backward. She's afraid to work. She's afraid to speak." By the early 1950s, the government-supported training center for blind boys was already in operation, and Radi wanted to offer similar opportunities to girls. Until her death in 1977, Istiqlal Radi devoted her energy, her influence, and her fortune to creating an environment where blind girls could develop to their highest potential.

Over the years, Al-Nour wal Amal has grown into a kind of conglomerate. Eighty girls and women live in the dormitory at the association's center in Heliopolis, a quiet, middle-class neighborhood in Cairo, and dozens of others commute to the center to study and work. About half the group attend a school accredited by the Egyptian Ministry of Education, with a full curriculum of primary and secondary courses. The others, enrolled in a rehabilitation program under the auspices of the Ministry of Social Affairs, manufacture carpets, basketry, socks, knitwear, and plastic bottles in the association's workshops. The sale of these products helps support the center and gives each worker a small salary (sometimes a major source of income for their families).

Junior trumpeters await rehearsal, left. Above: A violinist tunes up.

The center tries to prepare all the girls for an independent life by offering training in physical education, cooking, and home economics. For those in the rehabilitation program, marriage is the most likely path to a life outside the center, and should a young woman get engaged, the association will help her put together a trousseau and even provide her with a wedding dress. The staff and volunteers will also help the couple find an apartment and get a telephone line—major issues in a city of ten million. For those who remain in the dormitory, the association will engage a lawyer, if necessary, to protect their interests in disputes over inheritance.

At an early rehearsal, the orchestra sounds as if it has transformed the Czech dance into something by Charles Ives.

Life in a dormitory can be hard on a little girl, but it is often the best choice. For example, Ma'ali Salaheddin, 11, who attends the primary school and plays the violin, seems to thrive at the association, to judge from her curiosity and general high spirits. She has a blind brother and three sighted sisters, and when she goes home on weekends and vacations, her parents' apartment gets crowded. The family lives in a small flat, with a refrigerator in the bedroom, a washing machine in the entrance hall, and a tiny sitting room filled with a complete suite of locally crafted Louis Quinze furniture—red velvet and thick gilt paint on roughly carved frames.

Ma'ali's parents love their daughter—her mother often visits her at the center, and her father proudly displays a newspaper photograph of Ma'ali with the training orchestra—but they believe that she is better off at school. For one thing, their apartment is more than an hour's ride by taxi (and even longer by bus) from Heliopolis, making a daily commute impossible. Furthermore, after all the expenses of the children's unsuccessful eye operations, the family cannot afford to buy toys for them, much less pay the equivalent of $100 for a violin for Ma'ali. Although Ma'ali and her brother are resourceful at devising games to play with the handful of toys in the house, the facilities are much better at the centers for the blind. Besides, says their father, they spend much of their time at home on the telephone, talking to their classmates. The children miss their parents and siblings when they are in the dormitory, but they claim that they are happy when it is time to go back to school.

Al-Nour wal Amal Association tries to prepare all the girls for an independent life.

Music and academics together seem to provide the best chance for success in the world outside the association. The younger musicians usually rank at the top of their class in school, earning high scores by national standards. Many go on to the university or the Cairo Conservatoire. After graduation, a number of the women have found work in teaching, government administration, or private business, thanks in part to a law (originally designed to assist veterans of the October War of 1973) requiring that handicapped people make up at least 5 percent of the work force in any organization with more than 150 employees. Rather than looking for charity, however, the women simply want the chance to demonstrate that they can do work that is usually reserved for a sighted person. "When we play," says Iman Fawzi, the bassist, "we prove ourselves as Egyptians, as blind people, and as women. We show the world what we can do."

"The first group of girls didn't know what they were getting into, and look what they've accomplished," says Samha el-Kholy, founder and director of the music program. "This younger generation will be even better, I'm sure of it." Professor el-Kholy, who for many years also served as the director of the Cairo Conservatoire, urges the group to maintain its high standards. "People are so kind," she says. "They think, 'Oh, these girls are blind, it's very nice that they can play at all.' But this is exactly what we are trying to avoid. Blindness should not be an excuse for mediocrity, but now I'm very sure that we have passed this phase. They have a special sound, they understand what Abu el-Aid wants them to do, and they play very well together. The crescendos and the diminuendos! And the ritardandos, oh my goodness, they do that so well! Sometimes I have my mouth open. How do they do it?"

When the orchestra prepares to rehearse a new piece, each musician learns her part separately by studying the Braille notation. Louis Braille was himself a blind musician, and his system—largely unchanged since its inception in 1829—can represent all the elements of a musical score. In contrast to standard musical notation, however, Braille provides an entirely linear description of the details of the music. The left- and right-hand parts of a piano piece, for example, may appear as separate paragraphs. The simultaneity of sounds, represented graphically in a visual score, is not immediately apparent.

Gradually, through touch and play, each musician adds successive fragments of the melody to her memory, fixing its shape. Once all the players have learned their parts, the conductor's real work begins. Abu el-Aid takes sections of the orchestra one by one and shows the women how their parts fit together. Then he re-

A girl in the dormitory, above, does her housekeeping. Right: A group visits the Pyramids. Top right: Women in the rehabilitation program ready a rug loom.

peats the process with two sections, then three, until he has put the piece together like a mosaic. The process is not easy even if the musicians have already heard the piece in recordings.

At the rehearsal of the Dvořák piece, for example, the orchestra sounds as if it has transformed the Czech dance into something by Charles Ives—simple, familiar tunes rendered interesting by staggered (and staggering) meters and the shrill dissonance of instruments just slightly out of tune. "Where are you, trumpets?" Abu el-Aid asks mildly, finally stopping the music. The trumpets remain poised at their players' lips while the Maestro points out where they missed their cue. Later, during a break, the Maestro seems a bit disappointed in their performance, but he reminds us, guests from abroad, that this was only the second rehearsal of the

Dvořák. "Later on, they'll play something that they have already done in concerts," he promises. "You'll see. It's like a computer: you put in the program, and it runs automatically."

When the musicians return, Abu el-Aid raps sharply on the lectern, with a ruler this time. "Tchaikovsky, girls," he calls out. "Chinese Dance. . . . One, two, three, four." The orchestra launches into the music without hesitation, and the Maestro puts down the ruler and walks away with a flourish, like a matador turning his back on a bull. The excerpt from the *Nutcracker Suite* seems a bit out of place on a July afternoon in Cairo, but true to the Maestro's word, the orchestra plays perfectly, with no direction or cues. The performance is precise, enthusiastic, and, perhaps, "automatic," but it is a great deal warmer and more human than any computer. And with a dozen violin bows moving in perfect synchrony, the orchestra looks as good as it sounds.

With a dozen violin bows moving in perfect synchrony, the orchestra looks as good as it sounds.

Two days later—rehearsal afternoon for the junior orchestra—the hallway is once more quiet and empty. Suddenly, three young girls come clattering down a stairway arm in arm; in a flash of yellow and purple and green, they rush down the hall and disappear through one of the doors. Shortly after, another girl follows slowly, alone, taking short, gliding steps; with her arms held slightly out from her sides, she seems to float gently in an adagio ballet. Other girls join the group, and soon the squawk of an oboe and the groan of a contrabass begin to echo through the rooms. Out in the hall, a clarinetist stands straight as a pillar with her back to the wall, alternately practicing Mozart and blowing green bubbles with her gum. In the shadows, a cellist caresses her instrument as she tries to memorize a new piece, running through a couple of measures of music and then pausing to check the music sheets lying under the strings. □

Cloud Harvest

Photographs by Gilles Saussier

Gamma Liaison

The Atacama Coast of northern Chile is one of the driest places on the earth; cloud banks regularly drift in from the sea, but even a brief rain shower is an extraordinary event. Until the early 1970s, the 350 residents of the coastal fishing village of Chungungo received all their fresh water and electricity from a system operated by a mining company extracting iron ore from a mountain ridge called El Tofo. When the company's operations closed down, so did the village's water supply. After that, the residents depended on a small supply of fresh water trucked in with the aid of government subsidies but still at great expense.

But sheets of nylon netting erected atop El Tofo have changed everything. Designed to wring moisture from passing clouds, they send water pouring through a pipe to the town below.

Chungungo's lack of precipitation can be blamed in part on the Andes, which block moisture-laden east winds from the South American interior. And when chilly, damp winds blow in from the Pacific, they meet the desert's hot, rising thermals, which suck up the water vapor in the air before it can condense

Fog collectors let about 30 percent of the mist flow through, while the rest collides with the nylon mesh. Some 10 million fog droplets must coalesce before a drop forms that is big enough to trickle down into a collection trough at the bottom of the net. Gravity does the rest. On a good, heavy fog day, thousands of gallons of pure water pour down a pipe from El Tofo to Chungungo's storage tank 2,600 feet below.

and fall to earth. The water in the stratocumulus cloud banks, however, meets the land as fog when intercepted by a mountain ridge like El Tofo.

The idea of collecting water from fog is not new. Arabian nomads discovered long ago that containers placed under certain trees during fogs would fill rapidly. And people have long recognized that some isolated stands of trees in desert regions (such as Chile's Fray Jorge National Forest, one hundred miles south of El Tofo) have been sustained for millennia by fog-derived water. Because of their dense coat of long, slender needles, pine trees seem to be especially efficient at collecting fog droplets.

Not until the 1980s, however, did a team of Canadian and Chilean researchers begin to develop the net technology to maximize fog collection. What they came up with is a simple, inexpensive system that needs no energy source.

Water is no longer a problem in Chungungo, especially during the summer months when fog is thickest. Faucets have been installed in village houses, and a bath, once a luxury not to be imagined, is now a possibility. Skin and digestive diseases that used to be rampant (the meager supply of water was prone to contamination) are now relatively rare. Given their success in Chile, the project's scientists have begun looking at numerous coastal sites around the world where fog harvesting could change peoples' lives. As for the residents of Chungungo, they are looking forward to the imminent arrival of another essential commodity: electricity.

Robert Anderson

Bob Marley Live

Reggae, Rasta, and Jamaica fourteen years after Marley's death

Text by Mark Jacobson • Photographs by Scott Thode

As I stand in front of Bob Marley's former home, at 56 Hope Road in Kingston, now the site of the Bob Marley Museum, watching busloads of Japanese and German tourists drive through the iron gate and park on the now blacktopped field where, twenty years ago, I saw Bob, Alan "Skill" Cole, and other Rastafarians play soccer, a perhaps appropriately cynical thought crosses my mind: well, at least the King of Reggae, the Lion of Jamaica, isn't buried in the backyard like a pet gerbil, the way Elvis is at Graceland.

Following the musician's death fourteen years ago (he would have been fifty last February) and other wrenching disasters—including the murder of Peter Tosh (one of the original members of Marley's trio, the Wailers) and the still unresolved litigation over Marley's reputed $30 million estate—the Bob Marley fan is thankful for small favors. Even as I walk past the bulbous statue of Marley done in cement, which looms, golemlike, over the front yard, and am led through the museum's somewhat meager collection of memorabilia inside the two-story, jalousied house ("Dis dere is Bob's blender, where he mix up healthy *ital* ['holy'] drinks. . . . Dis is de tree 'bout which Bob wrote 'Three Little Birds'. . . . Dere's Bob's rusted bicycle. . . . Dere's a buncha articles written 'bout Bob"), it is not difficult to remember another time.

This was the early fall of 1975, scant months after the fall of Saigon, when the properly stoned observer might easily have mistaken the small but culturally fecund island of Jamaica in general, and 56 Hope Road in particular, for the temporary center of the universe. Back then it seemed that no one had ever encountered anything as splendid as Robert Nesta Marley (already the most famous man in Jamaica but not yet the huge international pop star he would become), sitting on the front steps of this ramshackle great house, dreadlocks hanging over his face, strumming out a few verses of his most recent local radio smash, "Jah Live." When he sang, reedily, "fools sayin' in dere heart/Rasta yar God is dead . . . The truth is an offense but not a sin/is he laugh last, is he who win . . . Jah lives," it was enough to make me weep.

I'll never know exactly why the often irascible-with-white-folks author of "Burnin' and Lootin' " chose to favor me with this private little concert, unless it was because he'd just saved my life, more or less, by shooing away several of his former associates from Trench Town. (Wielding machetes, they had accosted me

The tour begins in Bob's herb garden, where the lone marijuana plant is described as "something that is used for smoking."

BOB MARLEY
MUSEUM

in the upstairs hallway of his house, stolen my ticket for the upcoming Wailers concert with Stevie Wonder, and locked me in the room that now contains "The Bob Marley Library.")

It was an emotional time. Haile Selassie, the emperor of Ethiopia, proclaimed Lion of Judah, alleged 225th direct descendant in a line back to King Solomon, the man worshiped by Rastafarians as Jah, or "the living God," had recently died. The brethren looked to Marley, the best-known Rastafarian in the world, to comment on this unsettling metaphysical development. "Jah Live" was his rejoinder. "Jah live because you can't kill God."

For me and other ex-hippie press junketeers, thoroughgoing secularists all, sent to Kingston's scruffy version of paradise to check out this new Big Thing, it was the defiance of Marley's reply, and its unimpeachable sincerity, that was so thrilling. To Bob, it didn't matter what the denizens of Babylon (the Rasta term for all that is not *ital* in the sight of Jah) said. Let them bring their dried-up rationalism, let them slice God's flesh with their sharp autopsy blades, claim to throw his so-called body in an unmarked grave, it didn't matter. The wicked cabal of back-stabbing communists, Vatican hypocrites, and corporate sons of pirate, slave-master fathers were all wrong. And Bob, along with his marijuana-smoking, wild-haired, Bible-quoting, prophecy-believing, guitar-playing crew were right: Jah live.

After all, given the steadfast free association requisite for a small bunch of people on an isolated Caribbean island to come to the fervent conclusion that the diminutive Haile Selassie—the inept and petty autocrat described in Ryszard Kapuscinski's scathing book *The Emperor*—was the living God on earth, the denial of the monarch's death was no big leap.

To gain a degree of insight into the brilliantly off-the-wall, modernist synthesis that is Rastafarianism, it is useful to know that, as recounted in any number of reggae songs, the cornerstone of the creed rests on a prophecy supposedly spoken by Marcus Garvey, the formidable Jamaican-born Pan-Africanist of the early twentieth century. "Look to Africa for the crowning of a black king; he shall be the redeemer," Garvey is held to have said, thereby playing the John the Baptist role in Rasta cosmology by alerting the brethren to the subsequent crowning of Selassie as the emperor of Ethiopia in 1930. But as detailed in Timothy White's definitive Marley biography, *Catch a Fire,* Marcus Garvey not only never made such a prophecy, he was actually publicly critical of Haile Selassie.

Not that this historical discrepancy would have mattered much to those Jamaicans for whom the beautiful island of the tourist ads was a Kafkaesque limbo-with-banana-trees from which they craved an exit and a solution. To them the entire slavery experience of their forebears was tantamount to a terrible nightmare from which they had awakened in "a strange land" as tragically misplaced, debased squatters. The prophecy led them to believe that they would be repatriated to a purified and glorious Africa. (Whether this millenarian vision was to come about through divine intervention or practical efforts was up for interpretation.)

Taking Selassie's princely name, Ras Tafari, for their own, the Rastafarians went on to find biblical justification for not cutting their hair, never eating processed food, and smoking "the herb of the land." Herb (which should never be called dope, because "no plant can be a dope") facilitated for the Rastas the proper state for much subsequent "reasoning." It didn't matter if the British-tutored, nose-to-the-grindstone Jamaican middle class berated the Rastas as skylarking layabouts whose philosophies made no sense. It certainly didn't matter if accoutrements like dreadlocks scared people out of their wits.

That was the thing about Bob Marley: he was a true believer. In 1975, no less so than today, that really was a Big Thing. Plus, the music was unbeatable. The first Wailers' albums to be released worldwide, *Catch a Fire, Burnin'*, and the subsequent *Natty Dread* (made after the breakup of the original trio—Marley, Peter Tosh, and Bunny Livingston), each lyrically seething with revolution, remain in the canon of the greatest pop records ever.

Best of all, from the down-home music fan's point of view, was that the Wailers didn't belch forth from the corporate vacuum. As anyone who saw the vigorous film *The Harder They Come* suspected, Jamaica was filled with Bob Marleys and Wailers and would-be Wailers. There was an entire hothouse music industry run by producers, players, and singers—seat-of-the-pants capitalists all, outfitted with

Marley became an icon in the Third World through his exhortation to "Get Up, Stand Up" and his condemnation of "de downpressers."

healthy stacks of scratchy 45s that were peddled from shoe boxes. The special brand of "roots" reggae played by Bob Marley was only the most recent mutation of Jamaican pop, which began with the Louis Jordan/Fats Domino-influenced "blue beat" in the early 1950s. Blue beat became the miraculous "ska" (as pioneered by the invincible Skatalites), which then became the love-man, vocal-dominated "rock steady" of Ken Boothe and Alton Ellis, followed by the angelic early reggae harmonies of the magnificent Heptones, Desmond Dekker, and a hundred more.

For the continuity-minded, that was another neat thing about Bob Marley and the Wailers: they'd grown up on the indigenous Jamaican industry, played every style (check out Bob's teenage ska vocal on "One Cup of Coffee," circa 1962), scuffled and suffered like dem artists must in de ghetto. When, infused by the brimstone idiosyncrasies of Rasta, they broke "wide," they were wholly themselves. A *real* Big Thing.

What no one could have guessed was how big it would become. By 1981, when Marley succumbed to cancer (supposedly the result of a soccer injury to his toe, which he refused to have amputated because "Rasta don't amputate"), the Wailers were unthinkably huge, with 100,000 people in attendance at a single show in Milan. One of the most eloquent artists of social unrest in the second half of the twentieth century, Marley became an icon in what used to be called the Third World through his exhortation to "Get Up, Stand Up" and his across-the-board condemnation of "de downpressers."

These days it is impossible to walk through any major city—from Bangkok to Bamako—without seeing teenagers wearing Bob Marley T-shirts. *Legend*, Bob's eternally selling "greatest hits" album, sells on. Tales of the Wailers' epic concert in newly independent Zimbabwe routinely include spurious details of prisoners breaking down the jail doors just to see Bob. With the passing years, the reputed number of escapees grows.

A few years ago, as we sat in a cafe in Lamu, on Kenya's coast, a dreaded-up Swahili guy in a Bob shirt laughed pityingly when I questioned his assertion that Marley was murdered, his cancer injected by the ruthless Mason-controlled assassins who have ruled the Vatican in the name of Satan for more than a thousand years. As it turned out, this wasn't just a lone nut spiel; a friend of mine heard a nearly identical saga in Indonesia a couple of years later. Needless to say, many in Jamaica believe the story. Marley iconography will only grow as a result of the recent publication by Marvel Comics of a graphic account of Bob's life and times (it is contained in three issues: *Iron*, *Lion*, and *Zion*).

More tangibly, there's little doubt that without the precedent of Bob Marley, the entire genre of "world beat" (contemporary music of the non-Western world) would have been far slower to succeed internationally, at least commercially. "For me, Bob Marley is very important," says Paul-Bert Rahasimanana, a k a Rossy, the dreadlocked master of accordion, *valiha*, and *kabosy*, who is currently the biggest thing in the vibrant pop scene in Madagascar, home of a local industry not unlike Jamaica's in its nascent days. "When I heard Bob Marley, I understood people around the world might like my music."

This sentiment is echoed time and again by musicians coming out of local pop-oriented industries. Baaba Maal, the noted singer from Senegal, and numerous Zairian "soukous" stars have all paid tribute to Marley, the enabler. Beyond this is the explosion of Jamaican-style reggae itself in Africa. Actively modeling themselves after Marley and other Jamaican stars, people like Alpha Blondy from Ivory Coast and Lucky Dube of South Africa have made international careers playing social-activist reggae.

"African reggae, it's like some 360 thing, mon," says Neville Garrick, the artist who drew several of Marley's album covers and now, with Bob's widow, Rita, administers the Bob Marley Foundation, which runs the museum. He notes the transcontinental cross-pollination of Latin rumba, mambo, and so on, which had their beginnings in African rhythms and then returned to the Mother Continent, becoming elemental to the development of soukous and Ghanaian "high-life," among others. "The music come from there, Jamaicans mix it up, it go back," Garrick says. Then he watches another busload of tourists drive through the gate at 56 Hope Road. "You know, mon," he sighs, "if I have known all this would happen with Bob, I would have been a prophet myself."

Garrick's assessment is borne out by a

NO PHOTOS OF MURAL
GIVETHANKS FOR THE BIRTH OF BOB FEB.6 1945

> To Rastafarians, the entire slavery experience of their forebears was tantamount to a terrible nightmare from which they had awakened in a "strange land" as misplaced squatters.

series of huge murals painted on the stone fence inside the museum grounds: Bob in Trench Town with Rita and the children; Bob with fellow Wailers Peter and Bunny as young "baldhead" ska musicians dressed in Vegas garb, their true shaggy-headed Rasta personas looming overhead; Bob at the famous 1978 One Love concert, where he shamed warring political leaders Michael Manley and Edward Seaga into shaking hands; Bob in Africa—this beside a gigantic picture of a rainbow with the words "give thanks for the birth of Bob . . . February 6, 1945." All in all, there must be several hundred photographs and paintings of Marley on the museum grounds: the happy Bob, the sad Bob, the triumphant Bob, the brimstone Bob, the sensitive Bob, and the sick, soon-to-die Bob.

This is the case throughout the country. Once hounded by the island's police to throw away his "little herb stalk," Bob, recipient of the Jamaican Order of Merit, is now an official national hero. They sell his T-shirts for $15 at the airport, feature him in the tourist literature. His picture is on telephone poles, inside restaurants, in every club. For sheer lionization, he's far surpassed the Lion of Judah, Haile Selassie himself.

"Bob was someone who came along at a certain moment. What he have to say was perfect for that moment," continues Garrick, his dreadlocks now flecked with gray. "To tell the truth, though, most of what Bob sang about, in Jamaica, things stay the same. They don't change. That's why Bob sells better today than ever. So it's wrong to say time pass Bob by . . . but it wrong too to say that time don't pass."

As one drives around Kingston these days, it seems so: some things are the same, some not. The town does appear tidier, more well-to-do. The economy, if not booming, certainly seems capable of erecting and supporting any number of shopping centers. Jamaica is not exactly mellow, but the old tension that pervaded even the smallest transaction seems to have fallen away, at least in what's called uptown and midtown.

On the other hand, downtown—Rema, Trench Town, and the rest, the corrugated-hut "concrete jungle" where Marley was raised and which was the inspiration for many of his best songs—looks as fearsome as ever. The "posse"-dominated culture of political violence in these slums that spurred the 1976 assassination attempt at 56 Hope Road (Marley was shot in the arm—the tour guides dutifully point out bullet holes left in the back wall) continues, albeit more on a siege level.

As for the local music industry, it soldiers on, pumping out the vinyl (yes, vinyl!—at least for the "domestic" market) at an unprecedented rate. What they mostly do these days is "dance hall," which any and every Jamaican will be more than happy to tell you is the "real" rap music, since rap was "invented" in Jamaica by such "dub-kings," "toasters," and "deejays" as Big Youth and U Roy. (Dem robbin' American Public Enemies, Tupacs, Snoop Doggy Doggs only stole it to mek dere lolife tribal gangsta ting.) The justification for such a claim aside, suffice it to say that dance hall covers a sociosexual terrain similar to the harder side of the United States version, except that the Jamaicans, as usual, are more in your face. The late Peter Tosh's take on the music that has come to dominate the Jamaican market—his streetwise, Rasta take—was that it was "all slackness, talk of bumbaclaat gun play and slamming what's 'neath lady's dress, 'bout soiled underwear and whatnot."

"The youth listen to what the youth listen to, can't fight against it," Garrick says, indicating that these days, the Rasta finds himself in a "pocket," with "dread" nothing more than "a fashion, like everything else." Several of the left-leaning middle-class intellectuals who were sympathetic to the Rasta ethos have left the island in disgust at the unchanging social conditions. When some dread artists were reported to have cocaine problems, Garrick tells me, it went a long way to destroying the Rasta community "as the image of the pure Nazareth." It's a systemic problem that won't soon be fixed because according to Rastas around the island, it's easier to get crack cocaine than ganja. Coke produces a different kind of "reasoning," to be sure.

Still, Bob Marley's shadow is long, pervasive. Gussie Clarke, owner of the Anchor Recording Company, one of Kingston's most modern 24-track, 24-hour-a-day recording mills, gets a bit misty when Bob Marley's name comes up. "Bob Marley is literally the single greatest example of what this industry, what Jamaica itself, can produce. Bob,

There must be several hundred photographs and paintings of Marley on the museum grounds: the happy Bob, the sad Bob, the triumphant Bob, the brimstone Bob, the sensitive Bob, and the sick, soon-to-die Bob.

he wasn't in it for the money; it was something else to him. I don't care what these kids say now, every Jamaican who thinks of himself as an artist wants to be Bob Marley."

Everyone in Jamaica seems to sing better than anyone not in Jamaica. Maybe it isn't Bob Marley in 1968, but it will do.

Not the Super Beagle, at least not anymore. "Yah, when I came up Bob was what I thought about," says the Beagle (his real name is Denzie Beagle), a sweet-looking guy in his thirties in an undershirt who wears a jewel-studded guitar charm around his exceedingly well-developed neck. "Bob can't be nothing but a hero, you know. But he pass on. . . . I got my own things to say. Today, I'm one of the biggest names on the island."

Tonight he's trying out a few new "roots" tunes at the Centerpole Club, the Super Beagle reports, so maybe I should stop by and check them out. "Sure," I say.

That night, it quickly becomes apparent that the Super Beagle is not exactly one of the biggest names of the island, and the club, rather than a straight musical venue, appears more in the go-go/barroom mode. The Beagle and his five-piece band are shoehorned into a stifling six-by-six storage room out back. "Ya, mon," the Super Beagle says. "Just doing a little practicing, you know."

If the slight misrepresentation of his position in the hierarchy of Jamaican pop stars makes the Super Beagle feel guilty, he does not show it. Nor does he seem sheepish about the fact that his repertoire, while including some of the advertised "cultural" tunes, also encompasses much dance-hall rapping, in addition to several old-style, rock-steady love ballads. As the Beagle later says, "In this day and age, good to remain flexible." Not that any of this is a problem, because the Super Beagle sounds terrific. Everyone in Jamaica seems to sing better than anyone not in Jamaica, and the Super Beagle is at least as good as most of them. Maybe it isn't Bob Marley in 1968, but it will do.

The next morning, when I go to 56 Hope Road one last time, my cab driver, a man in his fifties wiping the sweat from his face with a handkerchief, provides me with some unsolicited insights: "It's hot today. In Jamaica, it's hot every day. Each year a little hotter, with not so much rainfall. When I was a little boy, I remember there was ample rainfall. The water soaked into the ground. You could breathe then. Now there is no ample rainfall, so the earth feels like it is dying. It folds up on itself, and reaches up till it starts to tear the meat from the bodies of human beings, ripping and tearing till there's only the bones, gleaming in the sun. That's what's going to happen to me, to you, and what happen to Bob Marley."

Over at 56 Hope Road, tourists from Munich pour in; they had their choice of the Marley museum or downtown Kingston for their day's excursion in the Jamaican capital. Their tour begins with Bob's herb garden, where the lone spindly marijuana plant is described as "something that is used for smoking."

"They keep coming," says Bragga, kneeling on his haunches. "That show even if Bob in his coffin, he don't die." Anywhere from fifty to eighty, Bragga has been around for a long time. He claims to remember me from my three-day visit twenty years earlier. This is ridiculous, but who knows? He also claims to have been with Bob when he wrote his first recorded song, "Judge Not," back in the early 1960s.

"Ya mon," Bragga says, talking a little slow so I understand half of what issues from his nearly toothless mouth. "In the cemetery yard, the boys were there, and I bring fruit from Coronation Market. All the boys want the biggest fruit. One take it, but the big one, it is not sweet. So Bob write 'bout the illusion of that. Judge not, before you judge yourself, judge not, if you're not ready for judgment, so why talk about me, someone else is judging you."

"There it is now," Bragga says, offhandedly. It takes a moment to realize what he is talking about. As part of the Bob Marley experience at 56 Hope Road, Bob's music plays incessantly on the sound system. Mostly it's the familiar international hits off the later albums, tunes like "Is This Love," "Jammin'," the new version of "One Love." It doesn't matter that these often weary-sounding songs, many made when Bob was already dying, cannot compare with the classic political tunes, stepping razors like "Concrete Jungle," "Mr. Brown," and "Small Axe."

Yet there it is, coming out of the loudspeaker. "Judge Not": the seventeen-year-old Bob, his voice up a couple of registers from where it would settle, innocent and brand-new. ☐

A World Apart

Text and photographs by Simon D. Pollard

Stepping onto the narrow, rocky beach on the north shore of Antipodes Island, I was confronted by a phalanx of seabirds lining Anchorage Bay like a wild and welcoming crowd. A deafening cacophony assaulted my ears as thousands of erect-crested and rock hopper penguins, squawking and fighting, burst forth in a chorus of stuttered screams. Light-mantled sooty albatrosses cried out like crazed soloists. From the mammal section came the low, guttural bellows of disgruntled elephant seals. The whole choir of the Antipodes barked its discordant message.

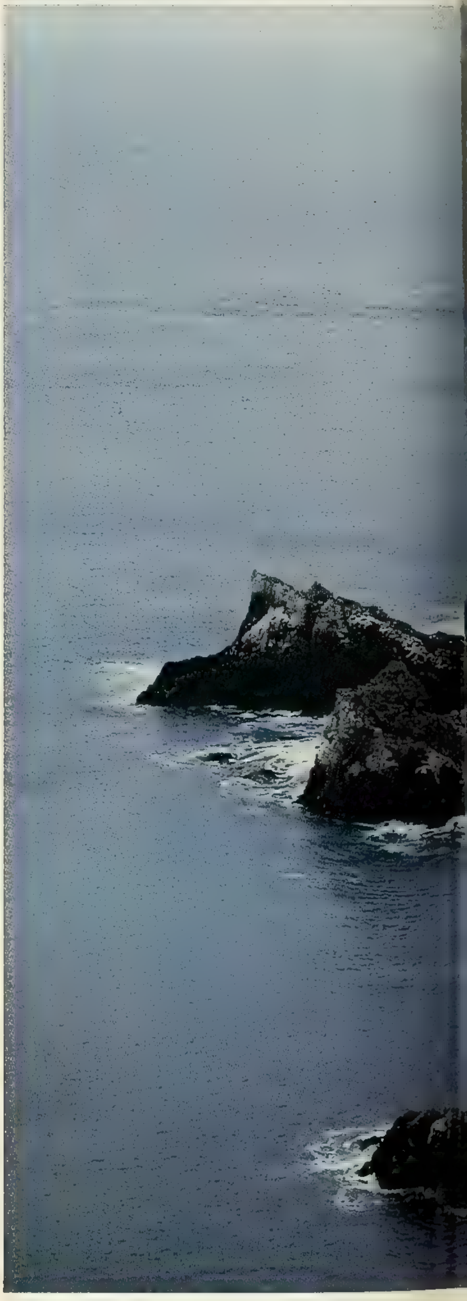
Perhaps the animals had a right to be indignant at our arrival; the twelve members of our expedition were among the few humans to set foot on Antipodes Island since the late 1970s, when New Zealand's Department of Conservation last sent a group of scientists to check on its inhabitants. Not only is the island legally off-limits to visitors, it is also hard to reach. The Antipodes are the most remote of New Zealand's five subantarctic island groups, which lie scattered like stepping stones to Antarctica. More than 500 miles southeast of the southern tip of New Zealand, the islands have no airstrip and can only be reached by a three- to four-day boat trip.

Seven and a half square miles in area, the main island is the remnant of an extinct volcano that emerged from the seabed 1.5 million years ago. It was built up by a series of eruptions characterized by huge fountains spraying out molten rock. The sea wore away the slopes of the ancient volcano, resulting in a dramatic coastline of rugged, crumbling cliffs, some towering almost a thousand feet above the surf. About a mile north of Antipodes Island, Bollons and Archway Islands form two-thirds of a sea-eroded volcanic crater, further evidence of the islands' fiery origins.

Rough weather can make landing on the rugged coast treacherous. The Antipodes lie in the latitudes known as the "roaring forties and furious fifties" and are pounded by huge seas, snapped at by persistent westerly winds, and chilled by cold fronts sweeping in from the Antarctic. Even a whisper of wind from the "roaring forties" can make landing on shore impossible, and the constant slapping of breakers against the steep cliffs and ragged rocks can easily smash a small landing craft to bits. Luckily, we arrived on a clear day, with the sea as gentle as the water in a rock pool. We had hitched a ride on the *Tui,* a ship from the New Zealand Navy that was delivering fuel to a research station on Campbell Island; by taking a circuitous route via Antipodes Island, they gave us a precious five days ashore.

The first people to discover the island were the sailors of H.M.S. *Reliance,* who sighted it in March 1800. The name Antipodes was chosen to reflect the island's position, which is almost exactly opposite, or antipodal to, Greenwich, England. The British often called the mainland of New Zealand the Antipodes because it was the most remote part of the Empire.

Our visit to Antipodes was a rare opportunity to study the island's ecosystem



Among the first animals to greet visitors to the Antipodes are erect-crested penguins, above, that nest near Anchorage Bay. Looking southward from Reef Point, right, the fortresslike shoreline of the islands is evident.

in relation to other subantarctic islands and mainland New Zealand. For shelter, the twelve of us moved into a three-room research hut built on Reef Point, just south of Anchorage Bay, during the last Department of Conservation expedition.

One of the disadvantages of life on the island quickly became apparent as we tried to move about. The coastline is fringed with six-foot-high clumps of tussock grass. The plant tops weave into one another in many places, making it difficult to get around, and it often took fifteen minutes of wading through waves of grass to traverse 150 feet. On the North Plains, 300 feet above sea level, the grassland vegetation is only a foot in height and much easier to walk over, compared with the coastline's tussocks.

I was invited by the New Zealand Department of Conservation to visit the Antipodes to survey the spiders living on the island, and I was especially interested to see whether jumping spiders (my favorite group) lived there. They are a hardy variety; some have even been found living at 23,000 feet on Mount Everest. In New Zealand's South Island, jumping spiders are common at high elevations, where they shelter in nests beneath rocks and crevices. Most jumping spiders are not web spinners; as they roam outside their nests, they depend on their excellent eyesight to detect prey, predators, and mates.

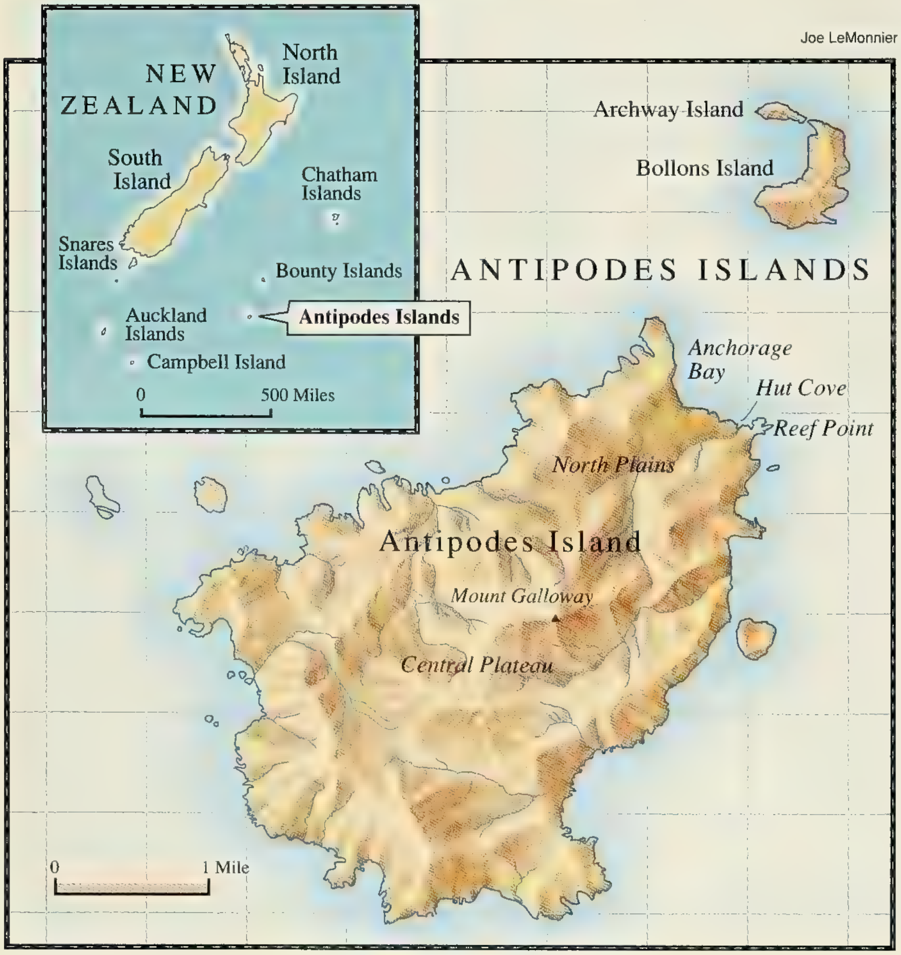
After a few minutes' search above Anchorage Bay, I found some dense silken nests clumped together under the rock outcrops. Closer examination revealed dozens of unblinking jumping spider eyes staring back at me. Although it is unusual to find mature jumping spiders clumped together, I suspect these were spending the

colder months (we visited in October, the austral spring) in their nests before emerging to feed and mate during the summer. I found a few other spider species, but jumping spiders were the most common.

Because cliffs ring most of the coastline, the island's penguins congregate in dense colonies at the few suitable sites where they can climb out of the water to nest. We were the first expedition to visit the Antipodes when the erect-crested penguins were laying eggs; this allowed Peter Carey and Colin Miskelly, from the University of Canterbury's Zoology Department, to further unravel the breeding biology of this little-known bird. Taking time out from the penguin colonies' deafening noise, they also estimated the size of the island's elephant seal and fur seal populations and surveyed the many other nesting bird species.

The most incongruous residents of the island are its parakeets. As I watched these birds flying among the penguin colonies and on the North Plains, they seemed as out of place to me as penguins would be in a tropical rain forest. One species and one subspecies are endemic to Antipodes, and although it is surprising that both could survive on such a small island, they have adapted to distinct food niches, thus avoiding direct competition. The larger Antipodes Island parakeet, considered to be the original colonist, feeds mainly on tussock and sedge leaves. Reischek's parakeet, a subspecies of the red-crowned parakeet found on one other subantarctic island and on New Zealand's northern offshore islands, is mainly a seed eater.

In a small cove just below the hut, I spent a number of hours with a male elephant seal, his harem of seventeen females, and their pups. The male was enormous, measuring some eighteen feet in length and weighing perhaps three tons. While the smaller fur seals use their front flippers to propel themselves on land, these appendages were useless to the male elephant seal. Instead, he undulated over the rocks like a gigantic slug.



Joe LeMonnier

While I was looking for spiders he was looking out for rival males and disgruntled females intent on leaving him—a seal "soap opera" was a wonderful distraction from peering under rocks. The females were constantly bellowing at one another and snapping at one another's pups. The male, acting like a couch potato most of the time, would occasionally leap into action to ward off the advances of a satellite male that spent hours trying to sneak onto the beach to mate. When the rival got too close, the resident bull would raise his head, bellow loudly, and move toward his competitor. This would send the suitor scuttling back out to sea until he felt confident enough to try coming ashore again.

Plot twists drive all soap operas and this one was no exception. I watched as the male left his harem to retrieve a female that suddenly tried to elope with the sneaky surfer. The male, his bellows reverberating out of his pouchy proboscis, great gobs of mucus erupting from his nostrils, rolled his blubbery body into the water. Transformed from a giant land slug into a sleek missile, he headed toward the couple at sea, and after beating up the opposition, he herded the female back to his beach, now and then holding her head underwater. Within half an hour, however, she made another, more successful attempt to escape and was reunited with her relatively diminutive suitor. Seething with resentment, the cuckolded male immediately mated with another member of his harem, then lolled around in the surf. He seemed unconcerned as I approached to within a few feet of his harem. I was pleased that he didn't regard me as a rival or, worse, a potential mate. Compared with the competition, I must have appeared a puny threat.

Soon after the Antipodes were discovered, hunters arrived on the islands and began killing thousands of elephant and fur seals for their skins and oil. In one year, a single ship carried off the skins of 60,000 fur seals, equivalent to about 60 percent of the entire fur seal population of New Zealand today. Within thirty years, the islands' seals had been nearly wiped out. Their low numbers today reflect the slaughter that took place almost two hundred years ago.

In the latter part of the 1800s and into the early 1900s, the New Zealand government sent search parties to the Antipodes to look for shipwrecked sailors. A survivors' hut, still standing today, was built on Antipodes Island in 1886. Graffiti scribbled on its walls from visitors long dead looks deceptively fresh, and only the dates betray the shelter's true age. To provide shipwreck victims with a food source, domestic animals and vegetation were introduced to the island.

The longest recorded stay on the island was made by the marooned crew of the *Spirit of the Dawn*. Their ship struck a reef off the coast in September 1893, and the eleven sailors survived for eighty-seven days before being rescued. They never saw the nine sheep and three cattle that were still alive from the earlier stocking of the island or the survivors' hut only two miles away from their camp. During their ordeal they sheltered beneath a cliff overhang in a structure built from turf and lived on limpets, giant petrel chicks, muttonbirds, albatrosses, the roots of a plant that tastes like celery, and, particularly, on penguins and their eggs. The sailors were lucky to have shipwrecked when they did, for the weather was relatively mild for most of their stay.

Fortunately for the island's fragile ecosystem, the introduction of animals for shipwreck victims was unsuccessful. Landing on the island must have been traumatic enough for cows and sheep, but the weather and difficult terrain proved to be too much for the animals to endure. The island also managed to escape the scourge of rats. Common castaways from ships, these aggressive rodents prey on the eggs and young of nesting seabirds, and have wiped out entire colonies on many remote islands. At some stage, mice made it ashore, but even though they are fairly common, they seem to have had little impact on the survival of nesting birds.

A territorial male southern elephant seal escorts a smaller female back to his beach in Hut Cove after her failed attempt to elope with another male.

The absence of introduced predators and scavengers was especially evident on the North Plains, where I could see hundreds of white dots dispersed among the fawn-colored vegetation. These turned out to be three-foot-tall white albatross chicks sitting on their nests waiting for their parents to return from the sea with food. Reminiscent of the Berlin airlift, a steady stream of adult albatrosses landed and took off in a tireless effort to keep their six-month-old chicks fed. With their nine-foot wingspans, the parents' agility and gracefulness in the air did not extend to arrivals or departures, with crash landings common, and frantic wing-flapping necessary for takeoff. The parents' lengthy foraging trips at sea would continue for another six months, until the chicks become independent. After leaving their nests, the birds will live on the open sea for seven years before returning to the island to breed. Each year, some 4,000 pairs of adult albatrosses, which breed every two years, return to the island.

The albatross chicks perched on their

Beyond the Roaring Forties

The Antipodes and New Zealand's four other subantarctic island groups are nature reserves managed by the Department of Conservation. Only Southern Expedition Tours Ltd. (P.O. Box 20219, Christchurch, New Zealand) runs excursions to the islands, as well as to Australia's Maquarie Island. Usually two trips aboard a polar research vessel are scheduled between November and January. Landings are permitted only on Enderby (one of the Auckland Islands), Campbell, and Maquarie Islands, but visitors are allowed to cruise the coastlines of Snares, Bounty, and Antipodes Islands in small, inflatable crafts. Attractions on Enderby Island include Hooker's sea lions, royal albatrosses, yellow-eyed penguins, Auckland Island shags, dotterels, and teals. Attractions on Campbell Island include elephant seals and royal albatrosses. Snares Island is home to Snares crested penguins, sooty shearwaters, and Buller's mollymawks, and Bounty Island hosts erect-crested penguins and Salvin's mollymawks.

For more information on New Zealand's subantarctic islands, see the guide book *New Zealand's Subantarctic Islands,* edited by Tim Higham, 1991, available from the Department of Conservation, P.O. Box 10-420, Wellington, New Zealand, and *Beyond the Roaring Forties: New Zealand's Subantarctic Islands,* by C. Fraser, 1986, available from the Government Printing Office, Wellington, New Zealand.

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Red-crowned parakeets blend nicely with the bright green of the moss-covered rocks near Reef Point, on Antipodes Island.

nests created ghostly landmarks at night as we descended from the North Plains to the research hut. Above this ethereal vision, thousands of petrels returning to burrows filled the night sky. Their landings conjured images of biblical plagues as they seemed to drop lifelessly to the ground.

My search for spiders also brought me into contact with large numbers of light-mantled sooty albatrosses nesting along the cliff tops, their feathers the color of dark, velvety mushrooms. I watched one get up from its nest and waddle comically to the edge of the precipice. It spread its wings, and as the wind slowly lifted it off the rock, its wide feet swayed in the air. It hovered briefly, as if suspended by unseen wires, and then flew off with a grace unimaginable moments earlier.

The seabirds seemed like fish out of water. Although masters of the air and sea, they are vulnerable and fragile on land, where they must venture periodically to breed. The sight of wandering albatross chicks dotted over the North Plains made it difficult for me to imagine how they could survive anywhere else. How could they sit there for a year without getting picked off by predators? In places where humans have introduced such predators as mustelids, rats, and cats, a similar scene would be impossible. Before humans landed on New Zealand's mainland, coastal areas that resembled these islands were filled with bird species now restricted to the Antipodes and a few other subantarctic islands.

The inhabitants of the Antipodes, however, continue to thrive because the cycle of life and death has, except for a brief period of human disturbance, essentially remained unchanged for hundreds of thousands of years. As I struggled across the tussock grass, I felt like I had traveled back to a time when humans had little impact on the destiny of other species. Few such places remain.

In the final verse of his poem "Unharvested," Robert Frost pleads:

> May something go always
>   unharvested!
> May much stay out of our stated plan,
> Apples or something forgotten and left,
> So smelling their sweetness would be
>   no theft.

As our inflatable landing craft pulled away from Anchorage Bay, the noise from its outboard motor drowned out the chatter of seabirds left behind. Soon we joined the *Tui* and were steaming toward New Zealand's mainland, leaving the residents of Antipodes, a paradise saved, to chatter noisily among themselves. □

Sewee Shell Mound, South Carolina

by Robert H. Mohlenbrock

A gently sloping zone that reaches from Long Island to Florida, the Atlantic coastal plain consists of sands, clays, and marls that were laid down over a very long period of time, from 140 million to 2 million years ago, as the ocean shoreline shifted back and forth. Located in a part of this low country immediately north of Charleston, South Carolina, is the Francis Marion National Forest, whose nearly 250,000 acres include bays, tidal marshes, upland ridges, and bottomland swamps. (It was in some of these swamps that the American Revolutionary War hero Francis Marion, known as the Swamp Fox, perfected his guerrilla tactics.) Among the forest's unusual attractions is the Sewee Shell Mound Historical Area, which includes the remains of two Indian shell middens, or refuse heaps, that lie close together in tidal marshland adjacent to the Cape Romain National Wildlife Refuge.

Human occupation of the region dates back to about 11,000 years ago, near the end of the last ice age, when Paleo-Indians living in small, mobile groups often camped along the coastal riverways. The animals they hunted included tapirs, mammoths, mastodons, and giant sloths. After the glacial ice retreated, the native population adapted to the warming climate, a rising sea level, and the disappearance of some of the large ice age mammals. Eventually, a pine forest came to dominate much of the coastal plain. From about 4,500 to 3,000 years ago, in what archeologists term the Late Archaic period, the inhabitants became increasingly sedentary, leaving behind shell middens, which also contained fragments of pottery.

First studied in 1965 by archeologist William Edwards, the older of the two middens at Sewee Shell Mound consists of tons of oyster shells deposited within and on top of a low, sandy ridge. This midden is about 415 feet across and is ring- or donut-shaped. Edwards estimated the highest part of the ring to be about 15 feet tall, but souvenir hunters and perhaps others seeking fill for roadways may have reduced it. In addition to oyster shells, Edwards found the remains of snails, clams, scallops, crabs, rays, several kinds of fish, turtles, alligators, birds, deer, raccoons, and opossums.

Edwards speculated that the site was used as a base camp where Indians dug fire pits, storage pits, and refuse pits, and built dwellings upon the accumulating mound. Based on the amount of refuse and on the type of pottery shards excavated, he estimated that the site was occupied for a period of 150 to 400 years. A few pockets of charcoal in the midden yielded radiocarbon dates of about 3,300 years ago.

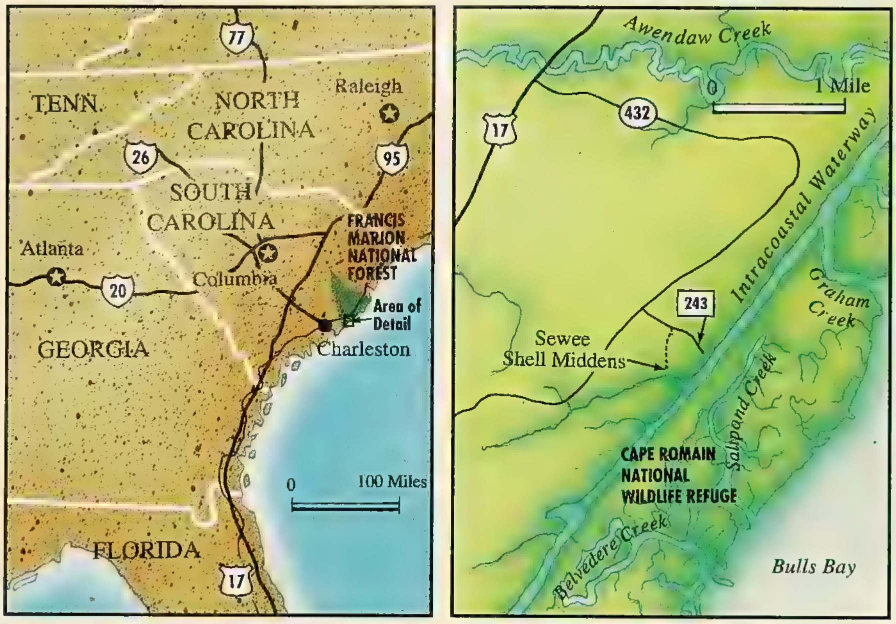
According to national forest heritage program manager Robert Morgan, current thinking is that the ring was a long-term habitation site or base camp and may have served as a gathering place where scattered groups came together to exploit the abundant coastal resources, share in communal and seasonal activities, and celebrate annual rituals. The ring shape may be the result of maintaining a cleared, central area for common use.

The second midden, which consists primarily of clam shells, dates to about 1,000 years ago. The two middens are named for the Sewee Indians, who did not create them but lived in the region when Charles Towne was settled by the English in 1670. According to W. J. Rivers's 1856 history of South Carolina, a small group of Sewees remained until 1715 but were wiped out when the Yamasee War was fought to control rebelling Indians.

I first visited the oyster shell ring in 1979, walking a short distance through forest to the tidal marsh. The marshland looked as though it would not support the

Vegetation grows over the edge of an ancient oyster shell midden, a garbage heap left by Indians who inhabited the tidal marshland of present-day South Carolina.

Walt Rhodes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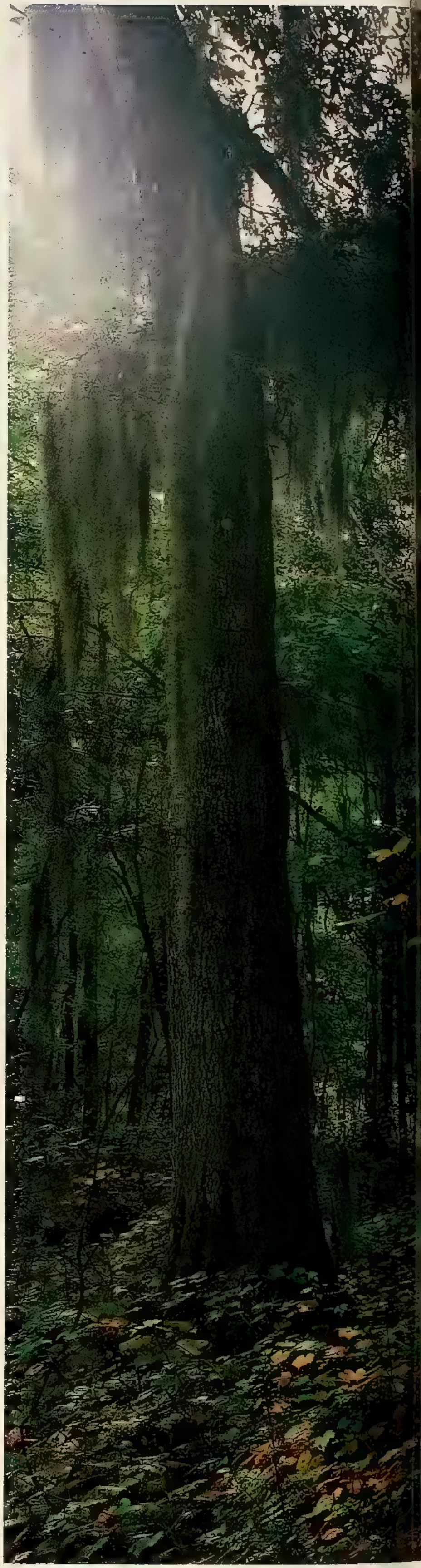
weight of a hiker, but the water-logged sand was surprisingly springy. During high tide, however, some of the mound is covered by several inches of water.

The plant life that I saw in the tidal marsh consisted of small species, many of them succulents, adapted to life in brackish water. The lowest-growing plants, usually not more than six inches tall, included glassworts, whose jointed, cylindrical, leafless stems turn crimson in autumn; sea blite; sea purslane (a type of portulaca); a fleshy leaved, pink-flowered member of the mustard family called sea rocket; a round-leaved creeping plant known as the smooth water hyssop; and a couple of salt-tolerant grasses—saltgrass and coastal dropseed. Growing up to a foot higher than these diminutive species were seaside goldenrod, the stiffly branched sea lavender, oxeye sunflower, narrow-leaved loosestrife, and two kinds of asters.

The maritime forest adjacent to the mound was unusual, owing to the more alkaline soil created by calcium from the oyster shells. Species rare or absent elsewhere in Francis Marion National Forest flourished under these conditions, notably small-leaved buckthorn and basswood. Other trees that were somewhat unusual for coastal South Carolina were bitternut hickory and Shumard oak. The handsome climbing hydrangea crawled over many of the branches.

When I returned to the site last year, however, this maritime forest had been leveled by the winds of Hurricane Hugo, which roared through Francis Marion National Forest on the night of September 21-22, 1989. In addition, the site suffered a devastating wildfire in 1991. Since then, the U. S. Forest Service has constructed an interpretive trail leading to the ancient middens, which have been included in the National Register of Historic Places since 1970. The oyster shell ring can now be viewed from a 120-foot-long boardwalk.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the U. S. national forests and other parklands.



Spanish moss drapes trees in Francis Marion National Forest, named for the American Revolutionary War hero who perfected his guerrilla tactics in the swamps.

David Muench

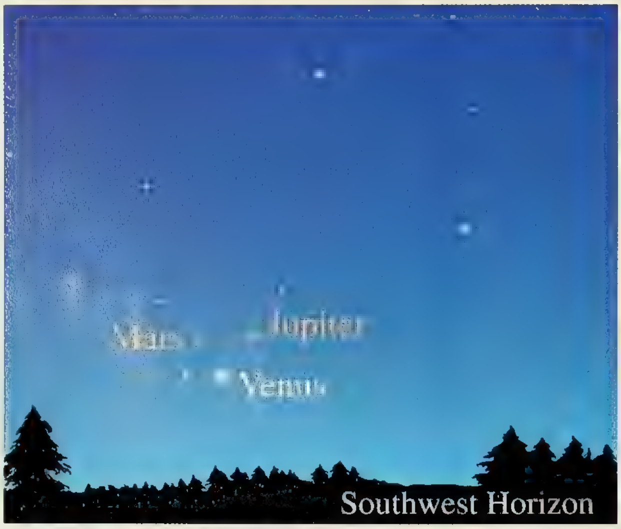
A Celestial Summit Meeting

by Joe Rao

This month, we will be treated to a spectacular planetary gathering as Venus, Mars, and Jupiter converge low in the southwestern sky. Such close groupings occur only once or twice a decade, but if you have ever visited a planetarium for a traditional Christmas show, you might have seen a re-creation of the close conjunction of Mars, Jupiter, and Saturn that occurred in 6 B.C. Astronomers and biblical scholars have long speculated that this close gathering might have been the phenomenon that came to be known as the star of Bethlehem.

Early in the month, Venus, the brightest planet, dips below the horizon about fifty minutes after sundown, but by the end of the month it sets in a totally dark sky more than an hour and a half after sundown. As Venus rises higher in the sky each evening, it gradually approaches its neighbors, dimmer Jupiter and the much-fainter Mars.

By November 16, the planetary trio forms a striking isosceles triangle low in the southwestern sky right after sunset. Try to find a place where trees and tall buildings will not obstruct your view, because the planets will be only about 10° above the horizon.



On November 19, Mars, Jupiter, and Venus will form a small triangle. This rare conjunction will be visible an hour or so after sunset.

Dennis Davidson

During the remainder of the month, watch each night as the relative positions of the three planets change. On the evening of the 19th, the trio forms its tightest grouping in a circle only 2° in diameter. The next evening, for the second time this year, Venus appears to pair off with Jupiter, which is only about one-seventh as bright. Meanwhile, Mars steadily recedes from the earth and grows progressively dimmer. It has kept pace with the sun since August, setting about two hours after sundown, but its solar conjunction is due on March 4, 1996, so its period of visibility is inevitably drawing to a close. On the 2d, it passes 4° north of the red star Antares, brightest star of the constellation Scorpius.

At 5:00 P.M., EST, on the 22d, Mars and Venus will come within eleven arc minutes of each other (a little more than a third of the apparent width of the moon). This will be their closest conjunction in ten years, not to be equaled in another ten. Mars, however, will be only one-hundredth as bright as Venus.

The next day is Thanksgiving, and at dusk, a very slender crescent moon (thirty hours after new phase on the East Coast) can be seen lying to the right of the three planets.

THE PLANETS IN NOVEMBER

The planetary motions of **Venus, Mars,** and **Jupiter** are described above.

Mercury begins the month rising about 10° south of east an hour before sunup, but each successive morning the planet appears a little lower in the sky as it moves toward superior conjunction on the 23d, when it will be on the opposite side of the sun from us.

Saturn, still in Aquarius, is almost due south as darkness falls, and it sets after midnight. On the 19th, sunlight begins shining on the southern side of Saturn's rings—the side that is now tilted away from the earth. Before the 19th, the rings can be

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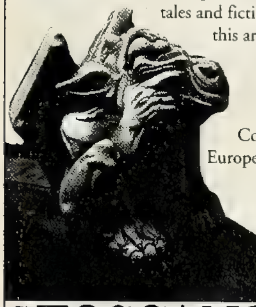

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glimpsed through a telescope as a narrow band of light, but afterward we will see them only as a thick, dark line bisecting the planet. The waxing gibbous moon passes 6° north of Saturn twice this month: on the nights of the 1st and the 29th.

The **Moon** is full on the 7th at 2:20 A.M., EST; last quarter is on the 15th at 6:40 A.M., EST; new moon is on the 22d at 10:43 A.M., EST; and first quarter is on the 29th at 1:28 A.M., EST.

The annual, mid-November **Leonid** meteor shower is famous for producing spectacular shows about every thirty-three years. In 1833, one observer compared the frequency of meteors to "about half that of the flakes of snow in an average snowstorm." In 1966, several thousand meteors per minute left observers awestruck. In recent years, the shower has averaged only ten or so meteors per hour, but with the source of the tiny particles that produce the Leonids (comet Tempel-Tuttle) scheduled to return in about two years, the rate of sightings per hour may pick up; truly spectacular displays may start in 1997.

Any prediction as to what meteors in the Leonid shower will do in a given year, however, cannot be much more than an intelligent guess. Spectacular showers were recorded in 1799, 1833, 1866, 1867, 1900, 1901, and 1966. Note, however, that no meteor storm occurred in the early 1930s, indicating that there might be large gaps in the Leonid swarm. In 1994 conditions seemed to be improving, but the shower was ruined by bright moonlight.

The height of the meteor shower this year will probably occur during the early hours of the 18th. Because the meteors approach the earth virtually head-on, they are extremely swift and often bright, with white, green, and blue colors predominating. Roughly two out of every three of the Leonid meteors leave lingering vapor trails. The meteor shower is so named because it appears to fan out from the constellation Leo, which does not begin to rise out of the northeast until after midnight. Anyone with a passion for meteors should bundle up against the chill of a late-autumn night and try to observe from about 2:00 A.M. until the first light of dawn.

Meteorologist Joe Rao is a guest lecturer at the American Museum-Hayden Planetarium.

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Recommended travel and reading from the authors of this month's features

Faeroe Islands

(Story on page 26)

The eighteen Faeroe Islands (seventeen inhabited) have a population of about 47,000, half of them living in two towns: the capital, Tórshavn, in the south and Klaksvík in the north. The language spoken is Faeroese, of which there are ten dialects, but everyone also speaks Danish and many speak English. The islands' dramatic scenery includes majestic sea cliffs as well as waterfalls, fiords, and beautiful natural harbors, such as the one in the small village of Gjógv.

Mykines, also known as Bird Island, attracts many biologists. Viewed from a distance, the island appears to be under a permanent cloud of mosquitoes. On closer examination, however, these turn out to be some of the half-million puffins that breed on the Faeroes. Throughout the islands there are also vast numbers of fulmars, storm petrels, kittiwakes, and guillemots, as well as gannets, Leach's petrels, shearwaters, red-throated divers, and great skuas. The oyster catcher, a protected species known locally as *tjaldur,* is the Faeroese national bird.

Visitors to the Faeroes can experience life as it was some 400 years ago. Many island houses are still roofed with grass, and many of the smaller villages have yet to catch up with the motor age; in some, the old cobbled streets are too narrow for cars, and others are accessible only by boat. At Kirkjubøur, south of the capital, there are medieval ruins, including the walls of a thirteenth-century cathedral, as well as what is claimed to be one of the oldest wooden houses in Europe, dating from about the fourteenth century and still occupied by a farmer. Traditional garments, made from the wool of sheep that bear a striking resemblance to the primitive Soay breed, are worn by many villagers on special occasions and at folk festivals, where traditional Scandinavian chain dancing, accompanying long folk ballads, is still performed.

Organized excursions, available through local tourist offices, are offered for salmon and trout angling, deep sea fishing, trekking, horseback riding, and bird watching. Whale drives occur most commonly in late summer, but the chances of seeing one are slim unless it takes place in the village where you are staying.

Getting around the islands is easy, but tends to be expensive. Buses serve most of the major road routes, and the islands are linked by an extensive and efficient system of ferries. During the summer, the best season to travel to the Faeroes, there are accommodations to suit all budgets, from hotels and bed and breakfasts to campsites and excellent youth hostels. Temperatures in the summer range from about 52° to 68° Fahrenheit, but the weather can be capricious, changing from brilliant sunshine to thick mist and back again in a matter of minutes.

The town of Vestmanna, on Streymoy Island, in the Faeroes

José Azel/AURORA

Standard flights into Vágar airport, on Vágar Island, arrive regularly from Denmark and Iceland, with extra service operating out of Glasgow during the summer. Car ferry service is also available from Denmark and Scotland.

For further reading on pilot whales, the author suggests Peter G. Evans's *The Natural History of Whales and Dolphins* (London: Facts on File, Inc., 1987).

BOB MARLEY
MUSEUM

Scott Thode

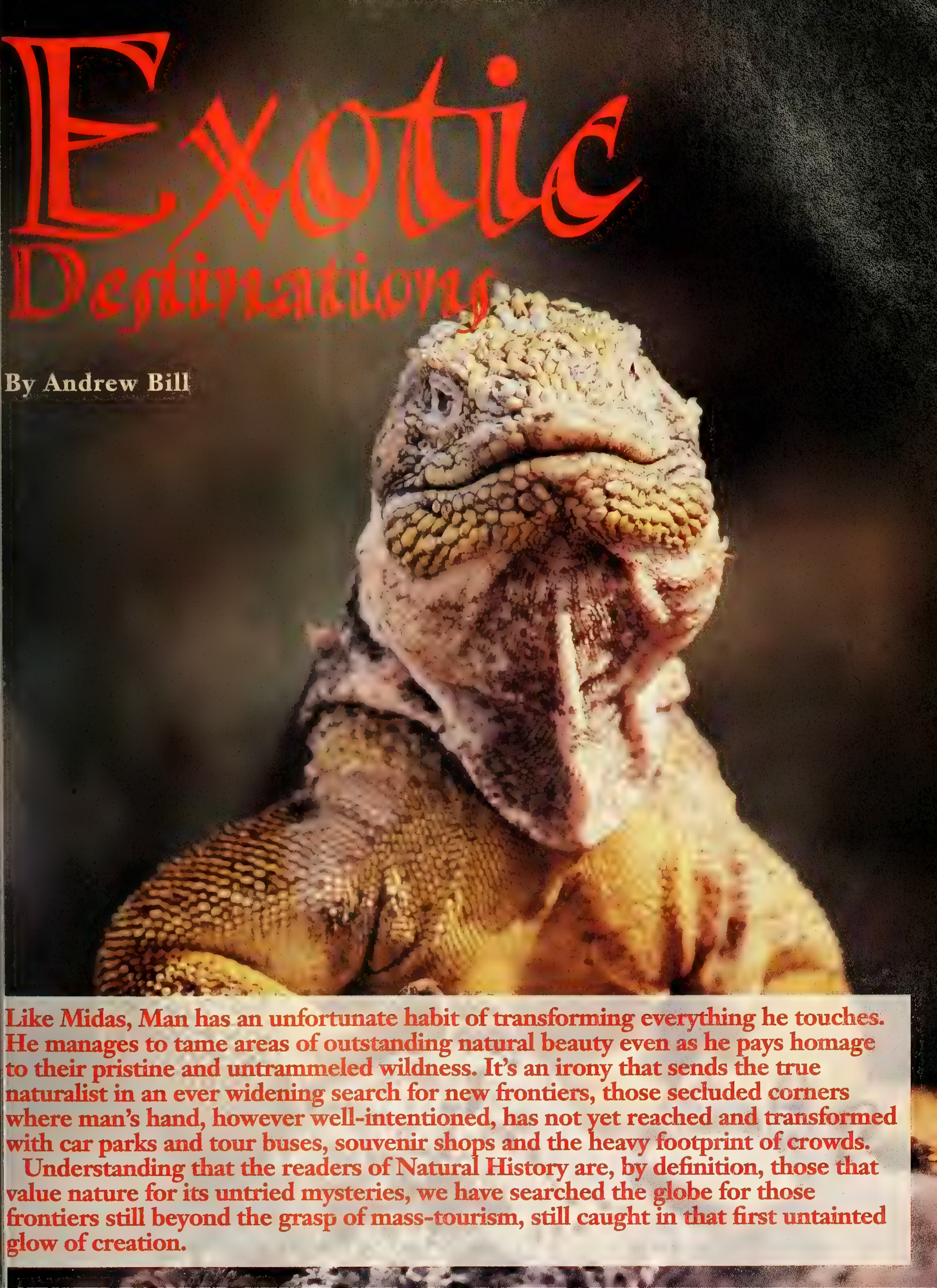
The Way to Reggae

(Story on page 48)

The best way to learn about Bob Marley and reggae music is to listen to the recordings. *Songs of Freedom,* a four-CD compilation of Marley's work, is the most representative example of his genius. *Tougher Than Tough,* a multidisc box from Island Records, gives a good overview of Jamaican music in general. (Also, see the movie *The Harder They Come,* made in 1972 but still pertinent.) The international music section in any large record store is sure to carry a selection of reggae music from Jamaica and elsewhere. A more specialized music store, Reggae Land, is located in New York City. According to the author, traveling around Jamaica in search of live reggae music can be daunting. But with determination—and a guide—you can hear live reggae there and in cities with Jamaican-American communities, such as Toronto, Miami, and New York. SOB's, at 204 Varick Street in New York, is a more accessible venue. A relevant magazine is *Rhythm Music* (872 Massachusetts Avenue, Cambridge, MA 02139).

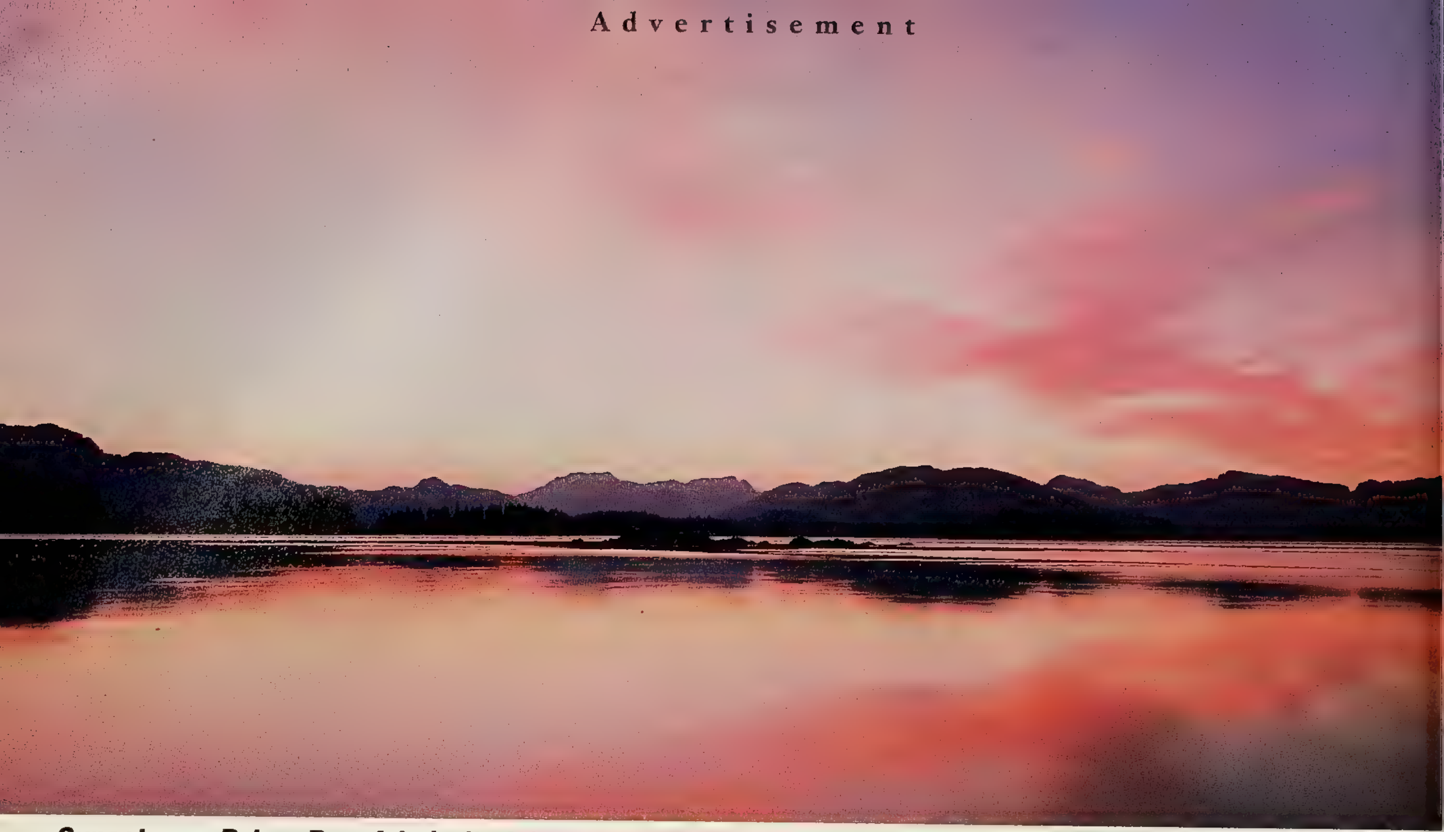
Exotic Destinations

By Andrew Bill



Like Midas, Man has an unfortunate habit of transforming everything he touches. He manages to tame areas of outstanding natural beauty even as he pays homage to their pristine and untrammeled wildness. It's an irony that sends the true naturalist in an ever widening search for new frontiers, those secluded corners where man's hand, however well-intentioned, has not yet reached and transformed with car parks and tour buses, souvenir shops and the heavy footprint of crowds.

Understanding that the readers of Natural History are, by definition, those that value nature for its untried mysteries, we have searched the globe for those frontiers still beyond the grasp of mass-tourism, still caught in that first untainted glow of creation.



Sunset over Pybus Bay, Admiralty Island Photo: Carr Clifton, Tony Stone Images

Cover: A land iguana of the Galapagos Photo: Laura Riley, Bruce Coleman, Inc.

Admiralty Island
Southern Alaska

Alaska is America's backwoods. In the popular imagination, it's where the mown grass and cement of civilization stops and where nature rises up immense, ungoverned and glorious. Since most visitors believe the best place to experience this wonder is in the great national parks, a quiet corner in the south of the state is left for the fortunate few.

Admiralty Island is not a national park, but a largely undeveloped national monument of nearly a million acres, just a short ferry-, charter boat-, or float plane-ride off the Panhandle (Juneau and Sitka are the main departure points). This is not Yellowstone, it's nature in the raw: footpaths leading off through stands of spruce, hemlock, and alder. Bald eagles screeching, their shadows carving smooth circles on the ground; black-tailed deer and moose surprised in the evening forage and, most important of all, 1,700 coastal brown bears (one of the world's largest populations). From viewing spots like Pack Creek you can watch them swiping salmon out of the falls or lumbering along the river bank. Many visitors tour the island by boat, viewing the marine life — seals, whales, sea-otters, and porpoises — then take shore excursions along the twenty miles of trails that crisscross the island. Others take the cross-island canoe route or hike the interior, camping at designated sites.

Those seeking accommodations should ask the Park Service about the fifteen public recreation cabins and the twenty private cabins under special use permit. The only permanent community on the island is Angoon, a native village with a rich cultural history. Best time to visit: the summer months when temperatures can rise into the eighties. For more information, contact the Forest Service Information Center, 101 Egan Drive, Juneau, Alaska 99801. Tel: (907) 586-8751.

Nambung National Park
Australia

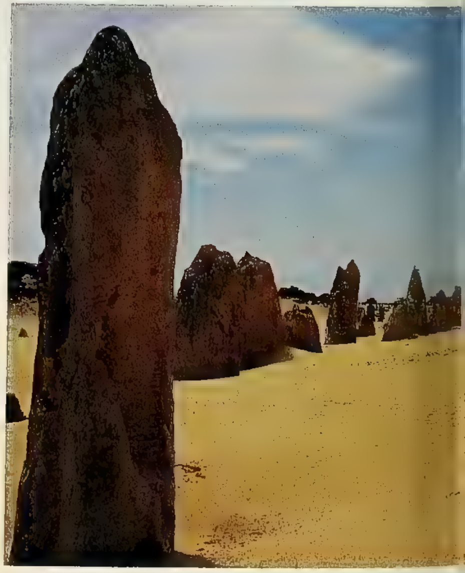
In Western Australia the landscape ranges from tropical swamps astir with alligators in the north to the temperate southern coast where whales swim the cool currents, and forests of vast karri trees rise into the sky. The bizarre is commonplace. But extraordinary even here is Nambung, famous for its eerie forest of limestone formations.

The park, just 162 miles north of Perth (a short hop in Aussie terms), clings to the western edge of a state three times the size of Texas. Visitors drive up in 4x4's to spend a day hiking the trails through low coastal vegetation of wattles, banksias, and scrub where wildflowers stand out like dabs of primary-color paint. After a hot walk, there is always the promise of swimming or fishing in the refreshing cool of the evening. But the main attraction is the Pinnacles, vast fossilized remains of an ancient forest that protrude from the red dunes like crude sculptures, beautiful in the changing light and resonant with earth power. Some are massive limestone mounds as big as cars; others are stalagmites as small and thin as pencils.

While there are no accommodations in the park itself, there are hotels in the nearby town. Best time to visit: August to September, when wildflowers are in full blaze. For more details, contact Nambung National Park, P.O. Box 62, Cervantes, WA 6511 or the Australian Tourist Commission in the U.S. Tel: (212) 687-6300

Rock formations of the Pinnacles

Photo: Ken Stepnell, Bruce Coleman, Inc



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Crooked Tree Wildlife Sanctuary

Belize

When a country has the world's second biggest reef just a boat-ride away from the shore, world-class diving in waters alive with fish, and coral of all hues, it's hardly surprising that much of the spotlight is directed sub aqua. But that's only half the story. Away from the coast lies the real Belize — dotted with ancient sites and the natural wonders of the tropics.

Established a decade ago to protect migratory birds, Crooked Tree is a patchwork of lagoons that thin first into shady dead-end waterways, then into logwood swamps — a haven for the hundreds of species that flock here in the dry season from November to April. And for ornithologists who come to this migration rest stop to study herons (night and great blue), ospreys, kingfishers, and muscovy ducks among hundreds of others. The big star of the show is the jabiru stork, the largest flying bird in the Americas with a wingspan of up to twelve feet. Touring the sanctuary — either on foot or on horseback along trails that wind through pine stands and grasslands, or by boat — you might chance upon one of the land mammals that keep close to the water like caymans basking in shafts of sun and howler monkeys kicking up a ruckus overhead, or turtles and iguanas scuttling away into the shadows.

Most notable of the many birds in Belize is the jabiru stork

Photo: Erwin and Peggy Bauer, Bruce Coleman, Inc.

Crooked Tree lies inland northwest of Belize City between the worthwhile Maya archaeological sites of Lamanai and Altun Ha. Available lodging ranges from a deluxe hotel to bed & breakfasts. For more information, contact the Belize Tourist Board, 421 7th Avenue, Suite 701, New York, NY 10001. Serious naturalists could also contact the Belize Audubon Society. Tel: 02-77-369.

Braulio Carrillo National Park

Costa Rica

Any naturalist worthy of his or her binoculars has heard the word about Costa Rica: twenty national parks; diverse ecosystems from arid, cactus-spiked parks to cloud forests saturated with fine mist.

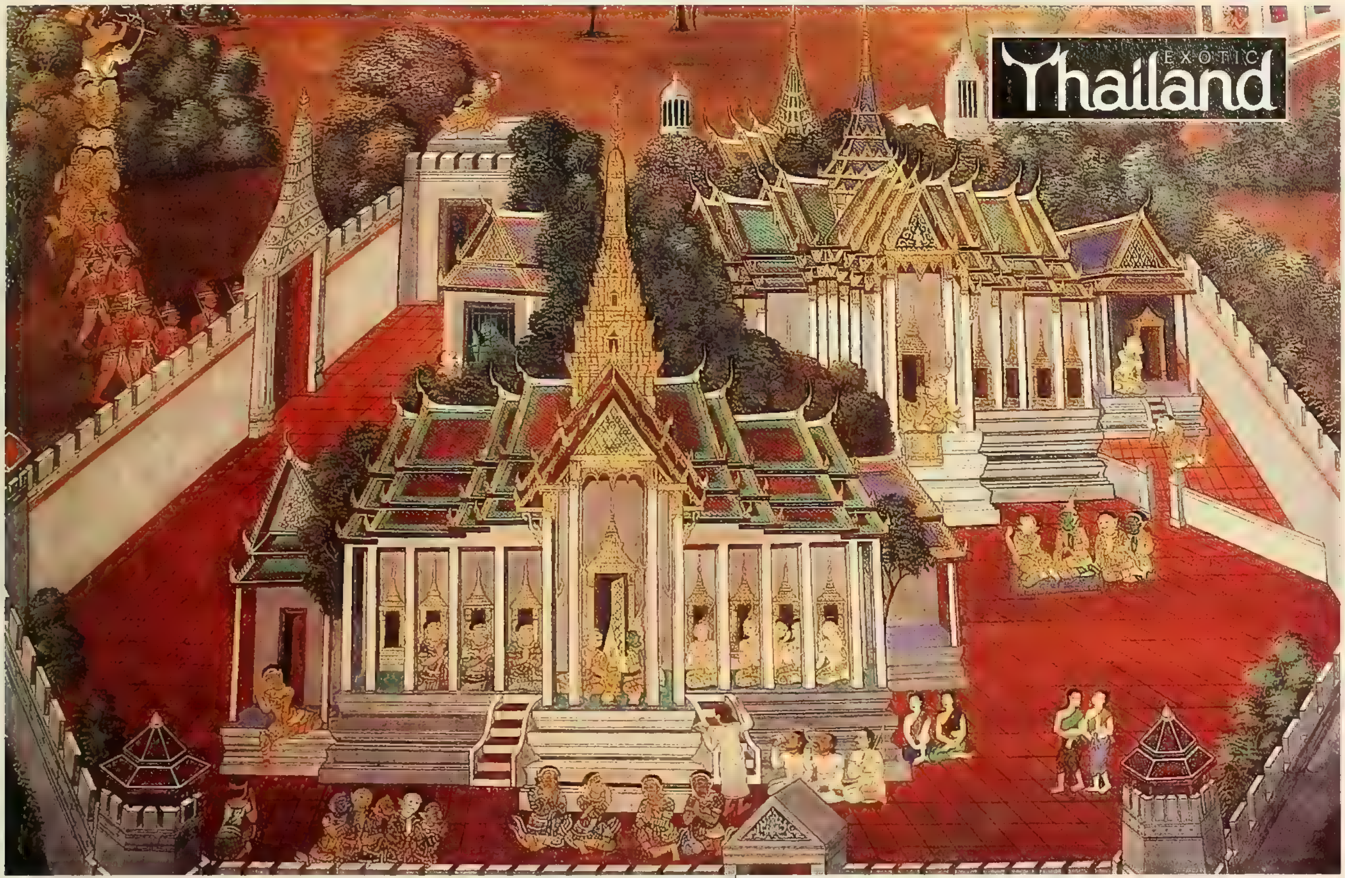
While some parks and reserves are accessible only with plenty of time, and a stout heart and vehicle, others — like Braulio Carrillo — are open to anyone with a free day and a good pair of walking shoes. Visible from the capital, San José, the park is high in the Central Volcanic Mountain Range. Rivers plunge down through primary, lush evergreen forests, clouds crown the peaks, bromeliads cling to branches clothed in moss, and flowers, in season, speckle the clearings. Anyone with the time to count can find 6,000 species of plant thriving in this nurturing climate. Others with a quiet step and keen eyesight can follow the barking to a family of howler monkeys thrashing through the tree-tops, or see tapir and deer feeding in clearings. Among the 347 species of birds at home here is the long-tailed quetzal, prized for its alluring plumage since the days of the ancients.

Large in area, the park can be approached from three different points. From the visitor center (Zurqí Station), a network of well-marked trails fan out across flatlands and peaks to swimming spots, lagoons, and the lips of two extinct volcanoes — the conic Cacho Negro and the many-cratered Barva. Even in the dry season (December to April), it is wise to pack rain gear. For more information contact the Instituto Costarricense de Turismo, P.O. Box 777-1000, San José. U.S. Tel: (800) 327-7033.

A waterfall in Braulio Carrillo National Park, Costa Rica

Photo: Stuart Westmorland, Tony Stone Images

Inside Thailand...



Mural Painting, Wat Suwanaram, Bangkok

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The Galapagos Archipelago

Ecuador

Since 1845, when Darwin used these thirteen rocky volcanic islands as the keystone for his theory of evolution, the Galapagos has also evolved...into a symbol. Apart from being one of the world's most spectacular and significant national parks, it also represents a successful marriage of preservation and tourism.

Often thought to be incompatible, these two forces are maintained through rigid control over visitor numbers, tour operators, and access sites. The result: 150 years after Darwin's departure, this most fragile of ecosystems has kept its balance in spite of — or perhaps because of — 40,000 paying visitors per year. Dropped at fifty-three access points by a flotilla of boats, these enthusiasts are still fortunate enough to see evolution in action, played out by the adaptive species of finches, tortoises, and iguanas. Swimming from the beaches, they are approached by inquisitive turtles, boisterous sea lions, and rays that flutter gracefully across the sand. Walking designated trails along cliffs and through bursts of petunias and yellow cordia, they have to step around blue-footed boobies, tropic birds and mockingbirds — none of whom have learned the notion of fear. Binoculars and zoom lenses are unnecessary. On each of the islands, the denizens have evolved beaks and behavior, shells and mouths, to suit the slight changes in terrain and available foods. The Darwin Research Station on the island of Santa Cruz is both an education center for visitors and a breeding farm for threatened species like the giant tortoise.

The Galapagos is reached by plane from the mainland cities of Quito and Quayaquil. One of the biggest operators, Galapagos Network, has a range of boats and tours lasting from three to seven nights. For information contact the company at 7200 Corporate Center Drive, Suite 309, Miami FL 33126. Tel: (800) 633-7972.

Nagarhole National Park

India

Most people think of India in terms of the major cities, teeming with colorful culture. Only a few experience the other side of the country, the many wildlife preserves that rank among the finest in Asia. For the true nature enthusiast, there is a little-known pocket in the country's less-visited center, formed by three adjacent parks — Bandipur, Kabini, and the newest of all, Nagarhole.

Although officially a sanctuary since the '50s, Nagarhole was promoted to a national park in 1975 in recognition of its rich habitats. Driving along its dirt roads and hiking along marked trails, you will encounter everything from swamps fed by the Kabini River to deciduous forests, pillared by the stout trunks of teak, rosewood, and ebony trees. Within the shadows lumber the big mammals — elephant and gaur (wild ox) along with the more discreet leopard, tiger, sloth bear, hyena, and the large Asiatic deer known as the sambar. For birders, the swamps and tree tops are home to eagles, hornbills, and buzzards.

The sambar, an Asiatic deer, is to be found in Nagarhole.

Photo: Tom Brakefield, Bruce Coleman, Inc.

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An Asiatic black bear of Thailand.

Photo: Nicholas DeVore III, Bruce Coleman, Inc.

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quite accurate account of the issue in doggerel verse, beginning:

Then Huxley and Owen
With rivalry glowing,
With pen and ink rush to the scratch:
'tis Brain versus Brain,
Till one of them's slain;
By Jove! it will be a good match!

And indeed it was. Private letters give a good account of the animosity. Huxley wrote that he would "nail that mendacious humbug. . . like a kite to the barn door." Owen described one of their public altercations to a friend: "Prof. Huxley disgraced the discussions by which scientific differences of opinion are rectified by imputing falsehood on a matter in which he differed from me. Until he retracts this imputation as publicly as he made it I must continue to believe that, in making it, he was merely imputing his own base and mendacious nature."

The "official" account of the debate can be summarized in a paragraph: Huxley approached the controversy like a military general, out to upstage an older enemy. He organized several colleagues to dissect the brains of various apes and monkeys, in search of the structures that Owen had pronounced unique to humans. Huxley himself studied the brain of the South American spider monkey, a "lower" primate on the traditional scale. They also scoured published literature, searching both for Owen's distortions or selective quotations and for prior proof of the three structures in nonhuman primates. In short, they found abundant evidence for all three features in various primates. Owen, according to legend, eventually shut up and licked his wounds.

Owen's tactics clearly led him to disaster. (Both Owen and Huxley came from lower-middle-class backgrounds, but Owen had ingratiated himself into upper circles, to his enormous practical benefit, receiving a rent-free residence directly from Queen Victoria and, beginning in the early 1840s, an annual civil list pension, all while Huxley struggled financially and grew bitterly jealous. Never doubt the centrality of social class for understanding Victorian life.) As a *nouveau arrivé* in the upper classes, Owen felt that he had to obey perceived norms for imperious disregard of upstarts. He fought for his positions and against Huxley, but not with the same vigor and with none of Huxley's overt organization. Owen largely tut-tutted among his noble friends and lost precious ground.

Owen's tactics evidently failed, but were his arguments so bad? I will not attempt to deny the usual reading—that Huxley and his phalanx found all three structures in the brains of nonhuman primates, therefore disproving Owen's criteria of uniqueness. But was Owen really so stupid and so defeated? I don't think so. I would like to raise two points for balance, and partly in Owen's defense—the first well discussed by Rupke and others, the second (so far as I know) not previously covered in the literature.

First, how did Owen respond to Huxley and company's discovery of the three structures in apes and monkeys? Did he just deny their findings or suffer in silence? In fact, Owen made a potentially fair reply. He had been stating for years (although he had conveniently omitted such a claim in several publications at the height of the hippocampus debate) that virtually every feature of humans has a homologous expression in closely related chimps and gorillas. (Owen had coined the term *homology* in the late 1840s to identify features of identical anatomical origin in different creatures, whatever the degree of functional divergence—wings of bats with front legs of horses, for example. We now attribute homology to evolutionary descent from a common ancestor.) But admission of homology does not require application of the same name to the relevant feature in two organisms, for functional divergence might legitimately permit a different term. For example, calling the bat's forearm a wing doesn't require us to state that all mammals have wings because all carry homologues of the bat's forearm bones.

> Huxley argued that the structural differences between humans and apes are far less than those between apes and monkeys.

Owen used a sneaky version of this purely terminological point to worm out of his defeat—but we must at least credit the technical validity of his claim. In the 1865 gorilla monograph, he admits that the three structures do exist in apes, but in such rudimentary state and in such different form from their expression in humans that all must receive a different name—just as horses don't have wings. Thus, we can still say that apes don't have a posterior lobe, a posterior cornu, or a hippocampus minor—even though they possess homologues of all these human structures.

Owen begins by allowing pervasive homology: "In the Gorilla . . . the homologue of every organ and of almost every named part in Human anatomy is present." He then discusses how a gorilla brain might be topologically transformed to a human brain, almost nonchalantly admitting at the end that the three structures already exist in gorillas:

> . . . to expand the cerebrum in all directions, and especially backward beyond the cerebellum, so as to define a "posterior" or "post cerebellar" lobe: to extend the chief cerebral cavity, or "lateral ventricle" . . . backward . . . into a "posterior horn". . . with prominences corresponding with . . .the "hippocampus minor"; the beginnings or incipient homologues of which cavity and part are alone present in the highest Apes.

I could accept Owen's redefinition as clever and honorable, but for two points. First, he implies that he doesn't have to give the same name to the three features in apes because they are so poorly developed in all nonhuman primates. But Huxley and colleagues had shown that some apes express these features as strongly as do humans. Second, if Owen had taken this position all along, then we could blame Huxley for unsubtlety. But in fact, Owen didn't begin by admitting rudimentary homologues of the three features in apes and merely claiming that strong human development required a separate name. He really did deny that the structures existed at all in apes. Owen wrote in his 1859 lecture:

> Posterior development [of the cerebrum] is so marked that anthropotomists have assigned to that part the character and name of a "third lobe"; it is peculiar and common to the genus *Homo*: equally peculiar is the "posterior horn of the lateral ventricle" and the "hippocampus minor," which characterize the hind lobe of each hemisphere. Peculiar mental powers are associated with this

highest form of brain. . . . I am led to regard the genus *Homo* as not merely a representative of a distinct order, but of a distinct subclass, of the Mammalia.

I do think, particularly in this context of such a strong conclusion, that "peculiar" means "unique"—and that Owen did shift his ground by verbal ploy, thus illustrating the valid part of Huxley's mistrust and anger.

But the second point, previously overlooked in our large literature, does validate an important part of Owen's argument—one with wrenching implications in our current reality. Huxley was clearly right in demonstrating the three structures in other apes, but his central presentation of the argument for evolutionary continuity between apes and humans, published most prominently in *Evidence as to Man's Place in Nature* (1863), rests upon two false arguments (one as sneaky as Owen's later attempt to hedge), both well refuted by Owen in his gorilla monograph of 1865.

Man's Place in Nature presents the strongest defensible version of smooth evolutionary transition between apes and humans. (Huxley admits the undeniable gap in brain size, with smaller-bodied humans carrying a brain three times as large as that of much weightier gorillas, but identifies this disparity as a gulf in quantity alone, for all parts of the brain are homologous in apes and humans. Huxley then, and with equal justice, argues that a different *quantity* of brain need not account for a true gulf in *quality* of mental operations, for such a claim would confuse correlation with causality. Perhaps, Huxley states, human cognitive superiority resides in some unidentified difference of cellular or microarchitectural function and not in disparity of bulk alone.)

Huxley then presents his two linked arguments. First, he hammers home by brute force, listing feature after feature, his key claim for continuity—the gap between the lowest ape and the chimp or gorilla is far greater than the corresponding gap between these "highest" apes and humans, so we are just one small step farther along in the sequence of apes:

> Whatever part of the animal fabric—whatever series of muscles, whatever viscera might be selected for comparison—the result would be the same—the lower Apes and the Gorilla would differ more than the Gorilla and the Man. . . . The structural differences between Man and the highest Apes are of less value than those between the highest and the lower Apes.

But Huxley's argument is invalid and

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self-serving within the context that both he and Owen shared: a belief that groups of related organisms should be ranked on a scale from lower to higher. (Our current denial of this scheme is, of course, irrelevant to our analysis of the logical structure of Huxley and Owen's arguments.) Owen properly refuted Huxley by pointing out that he had made a false comparison of disparate things—apples and oranges in the current cliché. The gap between gorilla and human amounts to one step, but the separation of "lower" primates from chimps and gorillas encompasses scores of omitted intermediates. If I were trying to minimize the gap between step 50 and 51 in a series by arguing that the separation between step 1 and step 50 is even greater, you would properly laugh me to scorn and say: don't load the dice inevitably in your favor; compare the right things. Tell me about the gap between 49 and 50 versus 50 and 51. A step must be compared with a step, not with entire series. If the step between humans and gorillas exceeds the space separating any between two adjacent primates, then I may regard humans as something special. Owen writes:

> Passing . . . to a comparison of the Gorilla's brain with that of other Quadrumana [apes], we discern the importance and significance of the much greater difference between the highest Ape and lowest Man, than exists between any two genera of Quadrumana in this respect. . . . From [gorillas] to Lemurs [the "lowest" primate in Owen's scheme] the difference of cerebral development shown in any step of the descensive series is insignificant compared with the great and abrupt rise in cerebral development met with in comparing the brain of the Gorilla with that of the lowest of the Human races.

I think that Huxley sensed the weakness of his argument, for he introduced a second supposed clincher in conjunction and support: the gap between gorilla and average human may be large, but if we order all human variation in a hierarchical ranking of races, from the "lowest" Negro to the "highest" Caucasian, then the gap closes, for the step from gorilla to lowest human is less than the space between lowest and highest *Homo sapiens*. (Please understand that I am using Huxley's own terms and quoting the conventional wisdom of his day within the restricted community of scientists—that is, white males of privilege.) Huxley wrote:

> The difference in weight of brain between the highest and the lowest men is far greater, both relatively and absolutely, than that between the lowest man and the highest ape. . . . Thus, even in the important matter of cranial capacity, Men differ more widely from one another than they do from the Apes.

I do not think that Huxley, a racial liberal by the standards of his time, advanced this argument with intent to impugn entire groups of human beings. Rather, he was trying to plug a hole in his central argument for evolutionary continuity by finding some way to fill the embarrassingly large space in cranial capacity between gorilla and average human.

This complex world of ours, this vale of tears, lies awash in irony. Just as bad things happen to good people, decent folks also advance logically fallacious and morally dubious claims in support of good arguments. Huxley stood on the side of the angels: he tried to advance the cause of human evolution by documenting continuity with our closest animal relatives. He closed his case with a magnificent prose flourish in describing the great range of design within the primate order, from the lowest lemur to our exalted selves:

> Perhaps no order of mammals presents us with so extraordinary a series of gradations as this—leading us insensibly from the crown and summit of the animal creation down to creatures, from which there is but a step, as it seems, to the lowest, smallest, and least intelligent of the placental Mammalia. It is as if nature herself had foreseen the arrogance of man, and with Roman severity had provided that his intellect, by its very triumphs, should call into prominence the slaves, admonishing the conqueror that he is but dust.

Whatever his broader good intent, Huxley did advance a harsh, uncompromising, and undeniably racist argument that arranged all humans in a line of increasing worth and explicitly identified African blacks as midway at best between gorillas and European whites. Huxley's error arose from a deep fallacy in his evolutionary reasoning—the progressivist equation of evolution with linear advance. He assumed that evolution must proceed in a series of rising steps, and he felt that he couldn't defend human evolution unless he could demonstrate such a linear order among modern people. In this assumption, he committed an even deeper error based on a classically false premise of reasoning: belief in continuity of cause and failure to recognize that superficially similar phenomena at different scales may have disparate causes.

Yes, humans differ from apes, and yes, humans vary among themselves. But these facts don't imply that variation in modern humans acts as a microcosm for larger differences between humans and other species—although Huxley assumed such continuity when he ran human racial variation along the same scale as differences among primate species. Human races are not surrogates for intermediate steps between ancestral apes and modern people: human races represent an entirely different scale of contemporary variation within a single biological species. We have no reason either to rank variation within a species along any line of worth or to regard such contemporary diversity as particularly related to modes of our evolutionary derivation. Of course, evolution does predict that the gap between ancestral apes and modern humans must be bridgeable, but the transitional forms are extinct species of the fossil record, not modern races. Moreover, since modern races are so young (as we now know), our differences are effectively inconsequential in evolutionary terms. No human race is, in toto, more apelike than any other. We are all recently derived varieties of the common human stock, *H. sapiens*.

"Whatever his broader good intent, Huxley did advance . . . an undeniably racist argument that arranged all humans in a line of advancing worth."

Poor, maligned, politically conservative, intellectually antediluvian Richard Owen. He took one look at Huxley's racist argument and nailed him—like a kite to the barn door, and exactly for the right reasons. I know that Owen did not refute Huxley in the service of racial egalitarianism. I know that Owen shared all Huxley's prejudices about racial ranking and the existence of higher and lower forms of human life. Owen's text is sprinkled with the language of a shared racist perspective. In 1859, he wrote that the chimpanzee lies "nearer than any other known mammalian animal to the human species, particularly to the lower, or Negro forms." And later in the same work: "In the low, uneducated, uncivilized races, the brain is rather smaller than in the higher, more civilized and educated races." In the 1865 gorilla monograph, he rolls all common prejudices into one line by stating that male skulls must be treated as standards, with both females and lower races (identified, conventionally, as Ethiopian, or African black, and Papuan, or Melanesian black) as inferior: "If the naturalist . . . were to abandon his proper guide, viz. the average condition of the brain in the male sex, and to take the brain of a female of the lowest Papuan or Ethiopian variety. . . ."

I also know that Owen refuted Huxley's racist argument in order to defend human uniqueness against a claim for continuity and not for any social or political motive that we might honor today. Nonetheless, intentions and consequences must be separated (and much of the fascinating complexity and moral ambiguity in our lives arises from the sharp disparity so often encountered between our goals and the opposite, yet unavoidable side consequences of actions taken in the service of these goals—oppose hunting on principle and too many deer may eat your flower gardens). Thus, I applaud the consequence of Owen's argument, whatever his intent.

Moreover, in this particular case, Owen's refutation of a racist argument did not arise accidentally from a claim advanced entirely for other reasons. I honor Owen even more because he knew exactly what he was doing—as he directly quoted the few egalitarian sources of his time and explicitly advanced his claim in the service of racial melioration (although not equality—an option that, sadly, did not exist in Owen's intellectual framework).

Owen refuted Huxley's second crucial point—that the gap from highest ape to lowest man did not exceed the space between lowest and highest men—by identifying human racial variation as both small in extent and fully encompassed within an indivisible species—in other words, as something different from the gaps between species. In the key passage, he writes:

> The extent of differences in the proportion of the cerebrum . . . in the different varieties of mankind is small, and with such slight gradational steps as to mark the unity of the human family in a striking manner.

But the most important sentence occurs two pages earlier:

> Although in most cases the Negro's brain is less than that of the European, I have observed individuals of the Negro race in whom the brain was as large as the average one of Caucasians; and I concur with the great physiologist of Heidelberg, who has recorded similar observations, in connecting with such cerebral development the fact that there has been no province of intellectual activity in which individuals of the pure Negro race have not distinguished themselves.

Owen then appends an interesting footnote:

> The University of Oxford worthily conferred, in June 1864, the degree of Doctor of Divinity on Bishop Crowther, a member of pure West African Negro race, who was taken from his native land as a slave, and recaptured in the middle passage. I record with pleasure the instruction I have received in conversation with this sagacious and accomplished gentleman.

(Samuel Adjai Crowther [1812–91], was captured from a slaving ship by a British man-of-war in 1822 and returned as a free man to Sierra Leone. Baptized in 1825, he attended mission schools in Africa and then traveled to England, where he was ordained in 1842 and consecrated in 1864. He then served as bishop of the Niger territories, where he translated the Bible into Yoruba.)

"Human races are not . . . intermediate steps between ancestral apes and modern people. They represent . . . variation within a single biological species."

Owen's passage surely reeks with paternalism by irrelevant modern standards, but we should honor his decency at a time when some colleagues wouldn't deign to socialize in any way with a black man. But Owen's most revealing words refer to "the great physiologist of Heidelberg"—for here we do grasp his unconventional allegiances. Friedrich Tiedemann, professor of anatomy at the University of Heidelberg, was the only genuine egalitarian among early-nineteenth-century European scientists of eminence. He measured skulls of all races and wrote several treatises on the putative intellectual equality of all people. He submitted a major article in English to the *Philosophical Transactions of the Royal Society* in 1836, the document quoted by Owen. If Owen explicitly cited Tiedemann, we can be confident that he chose to refute Huxley's argument on race, at least in part, by defending the high intellectual achievement and capacity of all human groups.

From 1859 until his death in 1870, Charles Dickens published a weekly miscellany of literature and current events entitled *All the Year Round*. He did not write each piece himself, but he exercised such a strong editorial hand that the *Encyclopaedia Britannica* remarks: "He took responsibility for all the opinions expressed (for authors were anonymous) and selected and amended contributions accordingly; comments on topical events may generally be taken as representing his opinions, whether or not he wrote them." Dickens published his major commentary on Darwin in the July 7, 1860, issue of *All the Year Round*. The closing paragraph reads:

> Timid persons, who purposely cultivate a certain inertia of mind, and who love to cling to their preconceived ideas, fearing to look at such a mighty subject from an unauthorized and unwonted point of view, may be reassured by the reflection that, for theories, as for organized beings, there is also a Natural Selection and a Struggle for Life. The world has seen all sorts of theories rise, have their day, and fall into neglect.

Owen's theory fell and died; Huxley's views prevailed, both by virtue of essential truth and possession of the right to tell history. But amalgamations usually represent our best solutions in a complex world—and I wish we had preserved Owen's correct and principled argument on race in proper integration with Huxley's evolutionary perspective. Such a conjunction, if incorporated into political and social policy as well, could have spared human history from most major horrors of the past century. We must still struggle to forge this conjunction, a tale of two worlds—for, in so doing, we might convert the "worst of times" to the "best of times," an "age of foolishness" into an "age of wisdom," and the "season of Darkness" into a "season of Light." □

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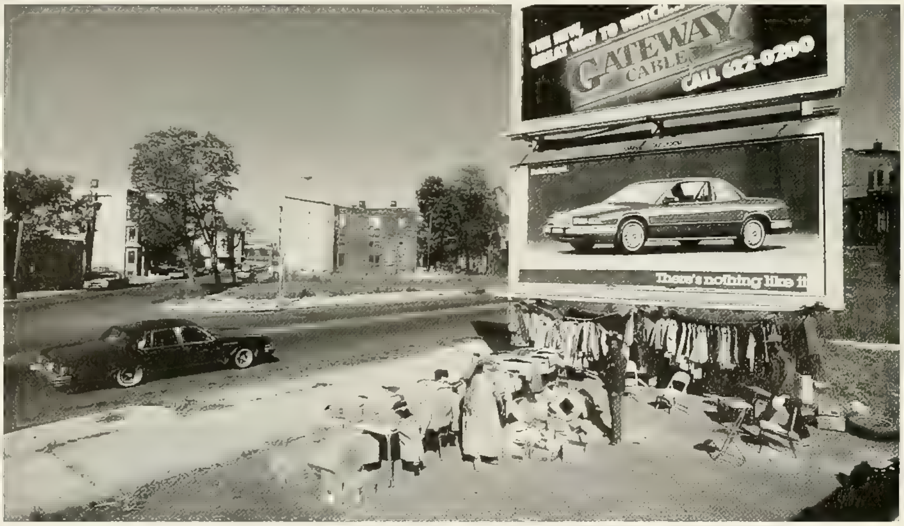

Church rummage sale, Newark, New Jersey

Camilo J. Vergara

Talons versus Tusks

In the midday heat of the Masai Mara National Reserve in Kenya, a martial eagle stood on a small mound amid the grasses of the savanna. Photographer Uwe Walz, peering through the sunroof of a Landcruiser, was thrilled by his luck but puzzled by the eagle's stance. The largest African birds of prey, martial eagles feed on a variety of creatures, often striking from the air. Walz readied the camera, expecting the huge bird, just yards from the truck, to take flight at any second. But the eagle ignored the vehicle, staring away. In a moment, the object of its scrutiny, a female wart hog with two piglets in tow, appeared and slowly approached the bird. The wart hog stopped, reconnoitered, and then lunged, trying to gore the eagle.

Now in fighting mode, the powerful bird flared its feathers and wings, hissing. Then, Walz notes, "in lightning moves, the eagle raised its talons and struck the wart hog again and again on its vulnerable nose. Finally, with its snout wounded, the wart hog was forced to retreat."

Right after this five-minute drama, Walz found the answer to the unlikely steadfastness of the eagle and the belligerence of the wart hog. The truck pulled closer; the martial eagle held its ground and kept its talons closed around its prize, the body of a third baby wart hog.—*Judy Rice*

Photographs by
Uwe Walz

Bare Bones of Tomb Rebuilding

BARE BONES OF TOMB REBUILDING

A replica of a 1,700-year-old tomb of a Moche warrior priest is now on display in the Museum's Hall of South American Peoples. Artifacts from the tomb were the centerpiece of the traveling exhibition, "Royal Tombs of Sipán" (*see* "Tales from a Peruvian Crypt," *Natural History,* May 1994). Working from detailed photographs of the site, on Peru's arid coastal plain, principal preparator Alec Madoff and his team from the Exhibition Department created the sixteen-square-foot display, developing new techniques in the process that allowed it to be easily dismantled and reassembled. The preparators fashioned eight sections of the tomb's walls out of six-inch-thick Styrofoam cut into interlocking pieces. The Styrofoam was then covered with a papier-mâché mixture to simulate the adobe brick of the tomb's actual walls.

The niches and groundwork were reconstructed in the traditional way: a wooden grid was built to match the contours of the tomb's base, and metal hardware cloth was stretched across this frame. After being soaked in plaster of Paris, one-foot-square pieces of burlap were applied to the frame and then covered with a layer of tinted papier-mâché. While still wet, the papier-mâché was textured and sprinkled with pebbles and soil to duplicate the look of the excavation scene. Reproductions of the skeletons of the warrior priest and those buried with him (including a dog) were constructed on removable Styrofoam pallets that were laid over the groundwork.

The bones found in the tomb, along with pots, figurines, gold and metal ornaments—even the dirt, rocks, and shells strewn about—were faithfully reproduced. The dirt was purchased from a theatrical prop store in Manhattan (at a cost of about $30 for a fifty-pound bag). Gary Sawyer, senior technician for the Anthropology Department, and preparator Mark Palkoski dug into the Museum's vast collection of bones to find good matches.

Replica of a Moche warrior priest's tomb
AMNH

From the Museum's collection of Moche pottery, Sawyer and Palkoski made waste molds or pottery templates, which they altered to fit the specific details of the pots found in the tomb's niches. Beads to match those in the once-elaborate, but now-disintegrating, neck mantle of the warrior priest were tracked down in New York's jewelry district and dyed to match the originals. The shells scattered at the base of the original tomb were identified by William Emerson, of the Museum's Department of Invertebrates, and he contributed similar shells—found on his collecting trip to South America in the 1950s—to the replica. Contemporary artisans in Peru who copy Moche jewelry sent samples of their work to the Museum, which the preparators "distressed" to make them appear very old.

Plans are now afoot to add a new wing to Peru's Brüning Museum at Lambayeque, near the Sipán tomb site. Archeologist and Brüning Museum director Walter Alva hopes that once the wing is completed, the replica can be disassembled, packed up, and permanently installed there.

NOVEMBER EVENTS

A new exhibition at the Hayden Planetarium, "Interpretations of the Cosmos: A Retrospective of Art Used in Planetarium Shows and Exhibits," opens on Wednesday, November 1. The Sky Show, "Cosmic Mind Bogglers: A Tour of Astronomical Extremes," focuses on phenomena in the universe, such as the recent, explosive comet impact on Jupiter. Call (212) 760-5100 for details about all Planetarium events.

As part of the Education Department's year-long program, "Multicultural Mosaic: Traditions of a Diverse Society," the Museum will host performances, workshops, and lectures during the "Celebrate India Festival," to be held on Saturday and Sunday, November 4 and 5. Traditional Banjar embroidery, Tamil Nadu puppetry, Bihar folk painting, and Uttar Pradesh jewelry will be among the offerings at the festival, which focuses on nomadic and women's traditions in India, as well as India's influence on the West. For a complete schedule, call (212) 769-5315.

Temperate and tropical American orchids will be the subject of two Tuesday evening talks, on November 14 and 21, at 7:00 P.M. The slide-illustrated lectures, taking place in conjunction with the Gallery 77 exhibition of orchid drawings from the Hunt Institute Collection, will be presented by Museum botanist William Schiller and New York Botanical Garden horticulturalist Keith Lloyd. Tickets are $15. Call (212) 769-5310 for more information.

This month's Membership Department programs include: Chemistry for Kids (ages 5–12), a demonstration by Saint Peter's College professor Patricia Ann Redden on Saturday, November 4, at 11:00 A.M., and at 1:00 and 3:00 P.M.; a talk on the legacy of Louis Pasteur on Thursday, November 2, at 7:00 P.M., by Professor Claude Hanoun; and storytelling, combining singing and narration, by Alice Eve Cohen on Sunday, November 19, at 11:00 A.M. and 1:00 P.M. Call (212) 769-5606 for information about membership programs.

The American Museum of Natural History is located on Central Park West at 79th Street in New York City. For information regarding the Museum's hours and admission fees, call (212) 769-5100.

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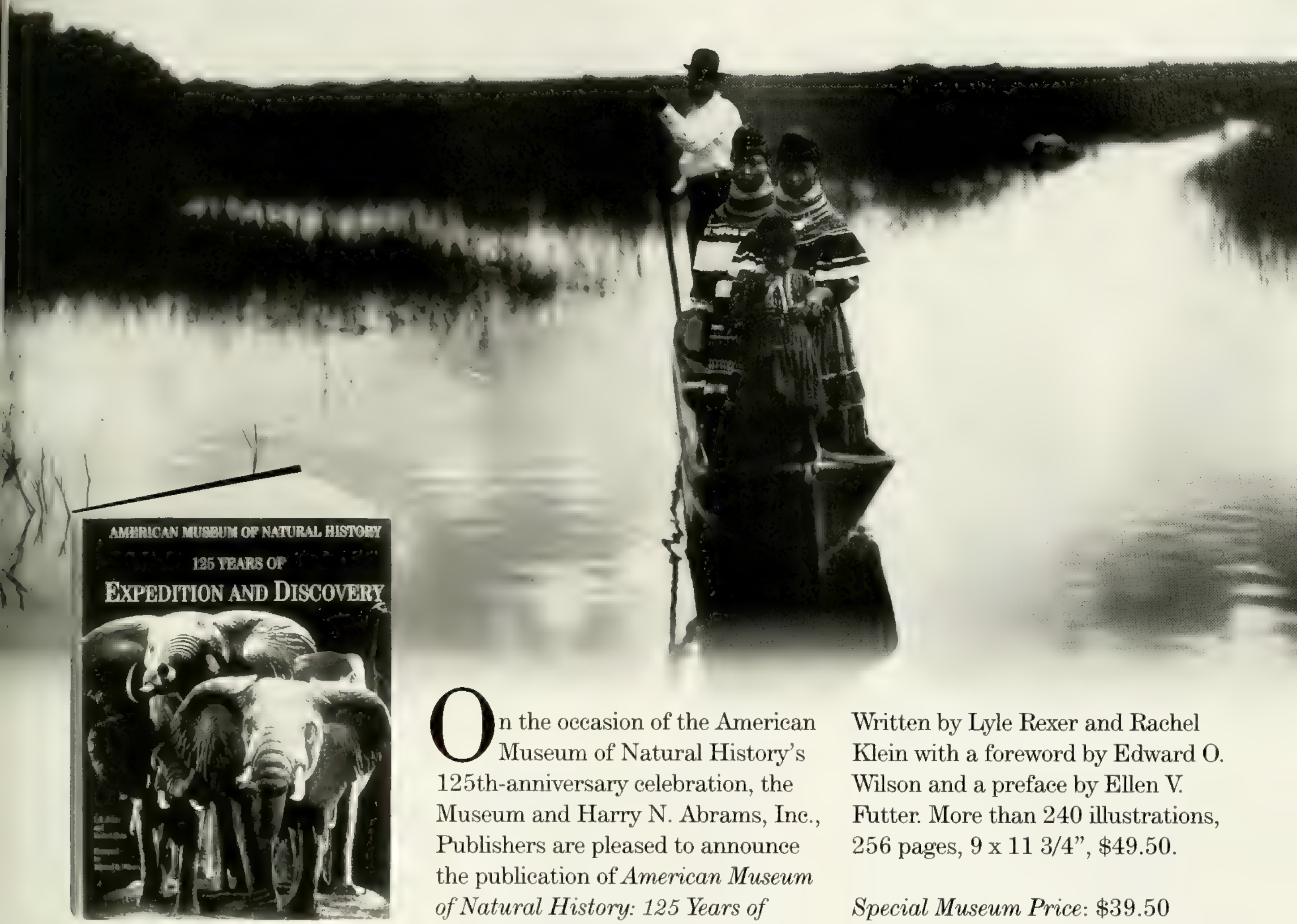

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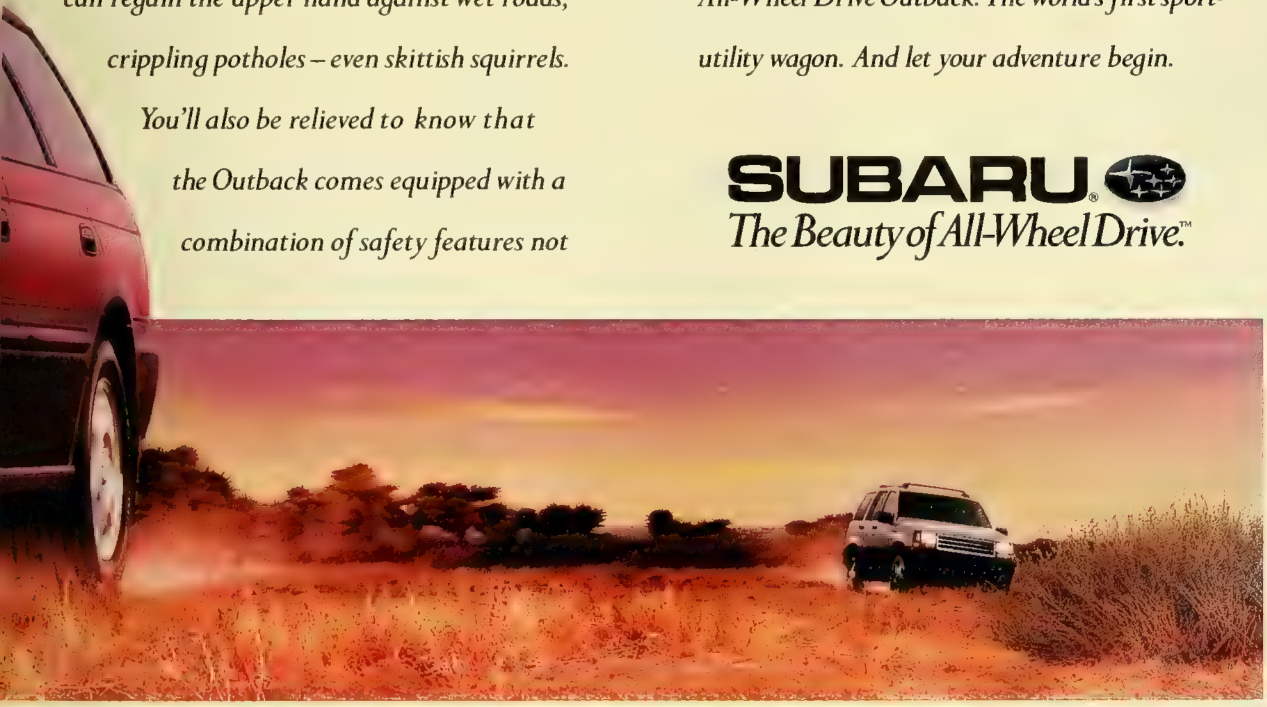

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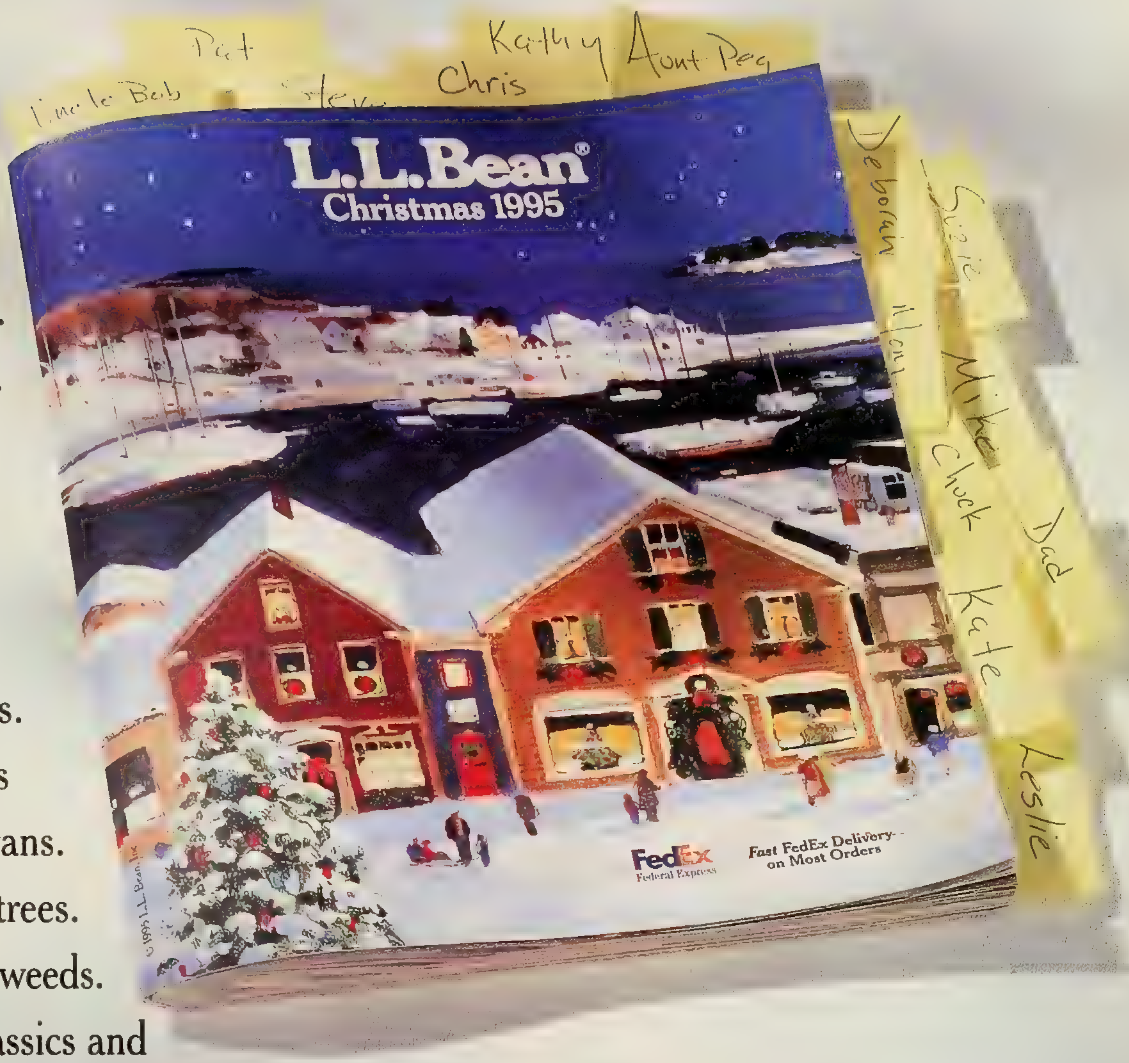
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Up Front

Rethinking Mothers' Nature

Motherhood was once assumed to be a safe topic. But no longer. The belief that mothers instinctively nurture their offspring—one of the West's most cherished ideals and a view widely accepted even in scientific circles—has been receiving bad press of late.

Social philosophers argue that mother love is a socially constructed attitude. They point to the high proportion of eighteenth-century European mothers who sent their babies away to be nursed by strangers. Some anthropologists reflect on whether mother love is a bourgeois luxury. They cite desperately poor women in third-world shantytowns who distance themselves from their doomed young. A rash of poetry and psychoanalytic commentary has also emerged, registering objections to what poet Adrienne Rich terms "the institutional violence of patriarchal motherhood," with its impossible ideal of mothers who not just willingly but "naturally" punch in for twenty-four-hour, lifelong shifts of unconditional love.

A special section on motherhood, with articles by Sarah Blaffer Hrdy, C. Sue Carter, Virginia Hayssen, and David Haig, begins on page 30.

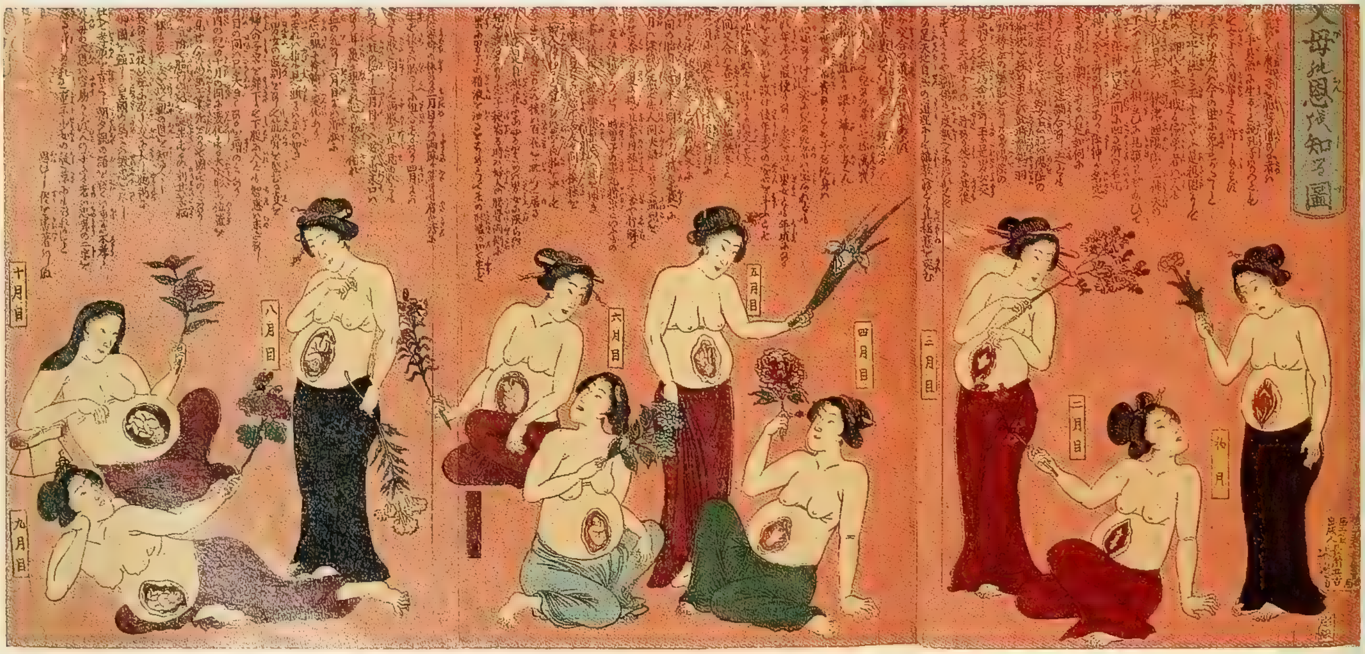
The debate between social constructionists (who view a mother's attachment to her infant as a learned, even indoctrinated emotion) and essentialists (who assume females are genetically programmed to be nurturing) has become so muddled that no one in either camp has paused to remark that in the real-life animal kingdom, not only is the essentialists' Empress of Maternal Instinct wearing no clothes, but she was never absolute ruler of the kingdom to begin with.

Some have glimpsed a silver lining in challenges to conventional wisdom. If, they argue, women are not programmed to nurture their young, then the parent with the XX chromosomes is no more innately equipped for childrearing than the father is. Hence, why shouldn't the bread-winning dad, just as well as the bread-winning mom, be expected to skip work when a child is sick? Furthermore, mothers need no longer shoulder so much blame when things go amiss. Gone then would be what Adrienne Rich so vividly identified as the dreaded "judgments and condemnations, the fear of her own power, the guilt, the guilt, the guilt"—perhaps the real "G spot" for mothers.

But what would such a reformation of the concept of motherhood mean, apart from creating a world safe for mothers to leave babies in day care and return to work? Is there any biological basis for a mother's attachment to her infant?

The answer, of course, all depends on what we mean by "biological basis." Much lip service has been paid to "biology," "instinct," and "natural laws" without a great deal of attention to how maternal behavior unfolds in the natural environments in which mothers live. Nurturing in mammal mothers can vary tremendously, depending on maternal condition as well as environmental and social circumstances. A mother dog that abandons some infants right after birth may hours later nurture and raise the rest. A mother mouse who kills her young in one phase of her life may make a model mother during another. As we consider the variety of conditions that confront human mothers, it might be useful to bear in mind that there is no universal maternal response—and there never has been.

Sarah Blaffer Hrdy



From Conception to Delivery, *by Sono Kochi Hasegawa*
National Library of Medicine, Bethesda

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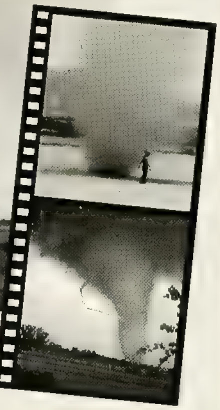

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DISTURBING CAKE . . .

I wonder how many readers winced at the photo of the two admirals, and the spouse of one, cutting a "victory cake" fashioned after an atomic mushroom cloud made to celebrate the bomb blast at the Bikini atoll in 1946 ("Up Front," July 1995). What a gruesome reminder!

It would have been more fitting—and less abhorrent—had they appeared in sackcloth and ashes.

REV. JOHN C. BATES
Middletown, New Jersey

David Burnett; Contact Press Images

. . . AND POLITICALLY INCORRECT PIE

I take umbrage at Roger Welsch's criterion for homemade pie ("Science Lite," October 1995): "The top and bottom crusts must be joined by the pinches of mother's finger and thumb." I was fifteen years old when Pop taught me how to make a light and flaky crust, how to use just the right amount of flour and sugar as filling, and how to keep it from lumping up. For fifteen years now, I have been the pie baker in my own family. So, if Roger Welsch or you can ever make it out to Seattle, please look me up. Dinner at my house with hot pie for dessert is yours for the asking. But please don't give Mom credit. She didn't teach me, Pop did.

DONALD BOOTHBY
Seattle, Washington

I found Roger Welsch's article on pies amusing, but I must object to his badly mangling a quote from a wonderful old anonymous nineteenth-century poem, "Dried Apple Pies." I have found it in *The Best Loved Poems of the American People*, edited by Hazel Felleman (Garden City, N.Y.: Doubleday, 1936), and for your information quote it here:

I loathe, abhor, detest, despise,
abominate dried apple pies.
I like good bread, I like good meat,
Or anything that's good to eat,
But of all poor grub beneath the skies,
The poorest is dried apple pies.

Give me the toothache or sore eyes
But don't give me dried apple pies.

The farmer takes his gnarliest fruit,
'Tis wormy, bitter, and hard to boot.
He leaves the hulls to make us cough,
And don't take half the peeling off.
Then on a dirty cord 'tis strung,
And in a garret window hung,
And there it serves as roost for flies,
Until it's made up into pies.

Tread on my corns or tell me lies,
But don't pass me dried apple pies.

JERE FRENCH
Gulf Breeze, Florida

NOTHING ESCAPES

In "Death by Black Hole," ("Universe," October 1995), Neil de Grasse Tyson writes at length about the enormous gravitational pull on objects approaching black holes. However, Tyson does not mention, much less discuss, the paradox that nothing escapes black holes, not even gravity waves: If gravity waves cannot escape, then how can we speak of a black hole's gravity field at all?

RICHARD H. SCHAEFER
Willoughby, Ohio

NEIL DE GRASSE TYSON REPLIES: Einstein's General Theory of Relativity explains gravity as nothing more than curvature in the fabric of space and time. Gravity is not itself an escaping wave. A *change* in gravity, however, will propagate as ripples traveling at the speed of light. These are gravity waves, and if formed inside a black hole, they will not escape.

PRAISE FOR CHANGES

Just a note to commend you on the astounding improvement in your magazine over the last few months. The writing, the topics, the design—the whole thing is a page turner. You have the edge in science, so if you can keep that up, while injecting the human element, you'll be unbeatable.

KATHLEEN M. KIELY
Winter Park, Florida

FISHY QUOTATION

In "This View of Life" (September 1995), Stephen Jay Gould quotes a line from Shakespeare ("Master, I marvel how the fishes live in the sea.") and assigns it to *Cymbeline*. The line, however, is from another late play of Shakespeare, *Pericles: Prince of Tyre* (act II, scene i, line 26).

LENNI BRENNER
New York, New York

You are right. Other readers also noted the slip, as we should have.—Eds.

Barbara Braithwaite, Swiftwater, PA

Margaret Tuthill, Shiprock, NM

Marty Gonzalez, Cypress, CA

THESE TEACHERS ARE BRIGHT, INNOVATIVE AND REMARKABLY CREATIVE. GEE . . . IMAGINE WHAT THEIR STUDENTS MUST BE LIKE.

Lois Crowley, Iowa City, IA

Irene E. Graham, St. Louis, MO

Marcia Spencer, Claremont, NH

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AUTHORS

A senior research scientist at the Australian Museum in Sydney, mammalogist **Timothy Flannery** ("The Great Leap Down Under") has conducted fieldwork in Australia, Indonesia, and much of the southwest Pacific. His interests range from paleontology to modern-day conservation issues. Flannery's new book, *The Future Eaters* (from which his current article is adapted), describes the effects the first Australasians had on their environment, as well as the ways in which the environment shaped them and their culture. Flannery has written several books about Australasia, including the recent *Mammals of the Southwest Pacific and Moluccan Islands.*

John Sexton ("Still Life") attributes his success as a landscape photographer to his parents for taking him into the forest at an early age and giving him the freedom to pursue his interest. From 1979 to 1984, Sexton served as technical and photographic assistant to Ansel Adams. Sexton lives in Carmel Valley, California, and teaches photography workshops in the United States and abroad. The image used for this month's "Natural Moment" was taken from his book *Listen to the Trees* (Little, Brown, 1994). To photograph the fallen tree, Sexton used his favorite camera, a 4" × 5" Linhof Master Technika view camera, equipped with a 210 mm Nikon lens.

Sarah Blaffer Hrdy ("Natural-born Mothers") is an anthropologist at the University of California-Davis, a middle-aged mother of three, an ardent advocate of breast-feeding, and one of five children. As such, she has had considerable firsthand experience observing maternal fitness trade-offs. One of her various hobbies, illustrated here, is allomaternal caretaking (a k a, being a mother's helper). Her essay in this issue is from a work in progress entitled *Mother Nature.* Also in this issue, Hrdy wrote "Liquid Assets" and coauthored, with C. Sue Carter, "Hormonal Cocktails for Two." In "Daughters or Sons" (*Natural History,* April 1988), Hrdy surveyed biases in parental investment throughout the animal kingdom.

David Haig ("Prenatal Power Plays") is currently an assistant professor in the Department of Organismic and Evolutionary Biology at Harvard University. He finds it odd that pregnancy is relegated to a relatively peripheral position in evolutionary biology in comparison with, for example, mating behavior. After all, Haig says, pregnancy lasts longer than many male-female relationships, and the mother-fetus relationship is at least as interesting. Much of his own research is devoted to understanding the evolution of pregnancy.

Growing up with a household of orphaned animals—from foxes and crows to snakes and crocodiles—**Virginia Hayssen** ("Milk: It Does a Baby Good") developed an interest in animal behavior early on. Years later, her scientific pursuits drew her to an almost equally diverse assemblage: red deer, bats, and deer mice. Currently on leave from the biology department at Smith College, Hayssen is a lecturer in the Department of Physiology and Environmental Science at the University of Nottingham, England.

C. Sue Carter ("Hormonal Cocktails for Two") is a professor of zoology at the University of Maryland. She has been studying the mechanisms of social behavior and attachment since she entered graduate school in 1966, but she traces her interest in the hormone oxytocin and its role in maternal behavior back to 1980, when her first child was born. Carter was coauthor, with Thomas R. Insel, of "The Monogamous Brain," in the August 1995 issue of *Natural History.*

On assignment to cover natural history toys for the magazine, **Howard Topoff** ("Child's Play"), professor of psychology at CUNY's Hunter College and a research associate in the Museum's Department of Entomology, was liberated from his usual summer routines of studying ant behavior and ecology at the Museum's Southwestern Research Station. "Instead of spending every afternoon under the blazing Arizona sun watching ant wars, I could go to the air-conditioned malls of Tucson and Phoenix to purchase toys and games and then go back home to play with the kids."

Diet is everything to **Perry Barboza** ("The Wombat Digs In"), who has studied the nutritional needs of a wide variety of animals. Such studies are being used to help conserve animals in zoos, as well as in the wild. As a Smithsonian Institution fellow, his fieldwork has taken him around North America to study seals, opossums, wolves, desert tortoises, and iguanas. Currently, he is an associate professor of biology at George Washington University in Washington, D.C.

An associate professor of anthropology at the University of Iowa, **Russell L. Ciochon** ("The Earliest Asians Yet") has traveled to China and Southeast Asia to explore paleontological and archeological sites in collaboration with Asian scientists. His most recent book, edited with Robert S. Corruccini, is *Integrative Paths to the Past: Paleoanthropological Advances in Honor of F. Clark Howell* (Prentice Hall, 1994), a multidisciplinary anthology of human evolutionary studies. Ciochon is currently working on a book with Jamie James for Oxford University Press on the archeology of Southeast Asia, and is scheduled to travel this January to the Pondaung Hills of upper Burma to search for the earliest fossil evidence of the anthropoids, the higher primates.

Born in Jacksonville, North Carolina, food writer **Robb Walsh** ("Getting Your Goat") graduated from the University of Texas in 1977, and now makes his home in Austin. A self-described "culinary adventurer" and former food editor of the *Austin Chronicle*, Walsh has researched stories about food and its cultural history throughout Europe, Scandinavia, the Caribbean, and North and South America, tasting as he traveled. His second cookbook, *Island Heat: Cooking with Caribbean Peppers and Hot Sauces*, will be published by Crossing Press this spring. Walsh's interest in goats is longstanding ("I have been eating *cabrito* for twenty-five years"). He is also the founder and head judge of the *Austin Chronicle*'s Hot Sauce Festival, the world's largest hot sauce contest.

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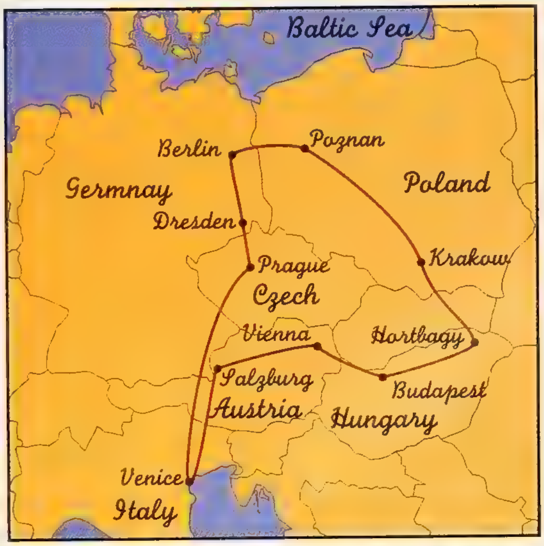

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THIS VIEW OF LIFE

The Anatomy Lesson

The teachings of naturalist Mendes da Costa, a Sephardic Jew in King George's Court

by Stephen Jay Gould

In Benjamin Britten's operatic setting of Henry James's *Turn of the Screw,* the boy Miles sings a little ditty to his governess during their Latin lesson:

Malo: I would rather be
Malo: in an apple tree
Malo: than a naughty boy
Malo: in adversity

Britten embodies all the fear and mystery of James's eerie story in setting this doggerel as a searing and plaintive lament that then cycles throughout the opera, emerging at the very end, but this time intoned by the governess as Miles lies dead on the stage. Britten's device works so well, in large part, because Miles's text is so insipid (and at the same time so expressive of his fears about personal evil). The English doggerel rhymes and makes sense, but the pedagogic joke lies in the fact that each of the four lines can be fully translated by the Latin *malo* (the first person singular of the verb *malle,* to prefer; the ablative of the noun *malus,* an apple tree; and so on).

Miles's poem, in fact, belongs to a venerable genre of crutches devised to make children love their Latin—obviously an ancient problem for teachers to overcome. Latin versions of various children's classics—*Winnie Ille Pu* most prominently among them—represent our most conspicuous modern effort toward the same end.

But children of the generation just before mine often encountered a much more pungent spur to their diligent study—namely, sex. Several men of my father's generation have told me that they applied themselves earnestly to the ancient tongue because some neighborhood kid always had access to his parents' copy of Krafft-Ebing's *Psychopathia Sexualis*—that great late-nineteenth-century compendium of case studies in every conceivable kind of sexual peculiarity (with a few making even Mr. Dahmer look relatively tame). The main text had long before been translated into English—but following Krafft-Ebing's own expressed wishes, all the juicy case studies remained only in Latin!

I missed all the fun. I never learned the kiddie mnemonics because I studied Latin only in graduate school. And I never relished the sexual prod because Krafft-Ebing's case studies finally made their way into English during my early prurient years. Thus I greatly enjoyed a little belated amusement last week when I finally got some ribald pleasure out of all that graduate school effort. But I wasn't reading Krafft-Ebing. I was studying a 1771 treatise on mollusks, *Fundamenta Testaceologiae,* by none other than Carolus Linnaeus (and never translated from its Latin original).

Yes, we are discussing clams—although Linnaeus seems to be talking about the sexual anatomy of women. Linnaeus's treatise begins in the stolidly conventional mode of most taxonomies. He states that he will classify mollusks by their shells (prized by naturalists who need schemes to order their specimens) rather than the animals within (biologically better, but rarely collected). He then makes a primary division into *Cochleae* (basically snails, with a few other single-shelled creatures thrown in, including scaphopods and even an errant worm tube or two), and *Conchae* (basically clams, or bivalves, but including multivalved mollusks, such as chitons, and a few creatures that don't belong at all by genealogy, including brachiopods and barnacles).

He then, still in conventional fashion, provides a list of technical terms for the parts of shells—and he begins his compendium for clams with one of the most remarkable paragraphs in the history of systematics. He states that the hinge between the two valves (*cardo*) must be a defining character, and he then writes: *Protuberantiae insigniores extra cardinem vocantur Nates*—or "the notable protuberances above the hinge are called buttocks." He then names all the adjacent parts for every prominent feature of sexual anatomy in human females—*ut metaphora continuetur* ("so that the metaphor may be continued"). Clams have a *hymen* (the flexible ligament connecting the two valves at top); *vulva, labia,* and *pubes* culminating in a *mons veneris* (various features at the top of the shell behind the umbones—our modern term for Linnaeus's buttocks); and, in front of the umbones, an *anus.*

Linnaeus's forced rationale for these terms can best be grasped from the picture he presents in illustration for a species that he named *Venus dione,* no doubt as a fitting moniker for his terminology. The illustration shows the full crudity of Linnaeus's supposed joke—for his terms record a complex analogy (not overly far-fetched, one must admit, in purely visual appearance) between a clamshell viewed from the top and the standard sleazy pose of pornography.

Linnaeus was socially conservative and rather prudish. He did not, for example, allow his four daughters to study French, for fear that they would then learn the liberal values of that enlightened land. But his taxonomic systems and his writings reveal the sexual focus that so often accompanies personalities of such overwhelming vigor and force. Linnaeus based his most celebrated work, his new classification of plants, on what he called the "sexual system." This scheme tends to be dry and functional, and not at all salacious—for the sexual system defines most orders

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University. He is also Frederick P. Rose Honorary Curator in Invertebrates at the American Museum of Natural History.

V. Lawrence '90

Vint Lawrence

by the numbers and sizes of stamens and pistils, the male and female organs of flowers. Basically, you just have to count—and Linnaeus's system became all the rage for ease of application, not for titillation.

But Linnaeus did follow out the metaphorical implications of his definitions. He referred to fertilization as an act of marriage, and he designated stamens and pistils as husbands and wives. Flower petals became bridal beds, and infertile stamens were eunuchs, guarding the wife (pistil) for other fertile stamens. Linnaeus wrote in an essay of 1729:

> The flowers' leaves . . . serve as bridal beds which the creator has so gloriously arranged, adorned with such noble bed curtains and perfumed with so many soft scents that the bridegroom with his bride might there celebrate their nuptials with so much the greater solemnity.

But these images are sweet Arcadian romances compared with the overt salaciousness of his terminology for the parts of clams. Consequently, Linnaeus took a great deal of contemporary flak about his names for the topside of clamshells.

In 1776 (a good year for reform) an obscure English naturalist, who lived a shadowy and troubled life (as we shall see), lit into the great master for his licentious malfeasance. In the preface to his *Elements of Conchology: or, an Introduction to the Knowledge of Shells,* the author wrote:

> One subject, however I shall insist upon; that is to explode the Linnaean obscenity in his characters of the Bivalves;. . . Science should be chaste and delicate. Ribaldry at times has been passed for wit; but Linnaeus alone passes it for terms of science. His merit in this part of natural history is, in my opinion, much debased thereby.

Late in the book, as the author comes to his chapter on clams, his fury has not abated. This time, he advances the explicit argument that Linnaeus's terminology makes natural history appear hostile to females, thus discouraging intellectual women from pursuing one of the few areas then relatively open:

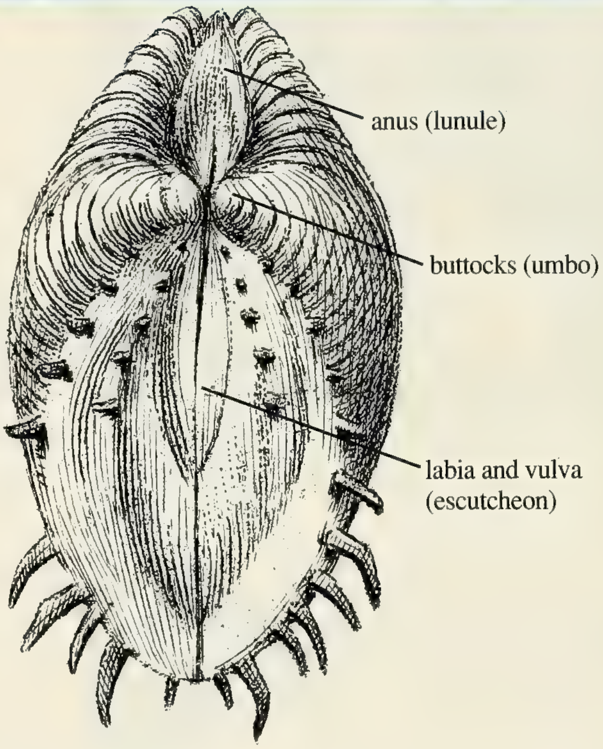
> I am the more desirous of fixing technical names, as the unjustifiable and very indecent terms used by Linnaeus in his Bivalves may meet their deserved fate, by being exploded with indignation; for
>
> Immodest words admit of no defense,
> For want of decency is want of sense.
>
> These my terms being adopted, will render descriptions proper, intelligible, and decent; by which the science may become useful, easy, and adapted to all capacities, and to both sexes.

(I originally assumed that the author's heroic couplet came from Alexander Pope, but my trusty *Bartlett's* tells me that the lines belong to an obscure character named Wentworth Dillon, earl of Roscommon (1633–1685)—a solid name indeed for poetic utterances of such unexampled propriety.)

The author of this book is Emmanuel Mendes da Costa, a Sephardic Jew of Portuguese origin who was born in London in 1717 and died there, in his lodgings in the Strand, in 1791. Although Mendes da Costa became one of England's most respected naturalists on the undefinable borderline between amateur and professional status, and although he maintained voluminous correspondence (much apparently preserved in the British Museum) with many of Europe's greatest naturalists and with most major players in the widespread network of British amateurs, his name has dropped almost entirely out of the historical record—except for two lovely books that frequently appear on the antiquarian market: the 1776 treatise on conchology, and his 1757 work, entitled *The Natural*

History of Fossils (I base this essay largely on these two works). I may well have missed some secondary sources, but I was unable to find anything about Mendes da Costa's life and works beyond a column entry in the British *Dictionary of National Biography,* a few bits and pieces in early-nineteenth-century volumes of *The Gentleman's Magazine* and, fortunately, about fifty pages of his fascinating letters, reproduced in volume four of an 1822 series by John Nichols entitled *Illustrations of the Literary History of the Eighteenth Century Consisting of Authentic Memoirs and Original Letters of Eminent Persons.*

I regard this erasure of Mendes da Costa as most unfortunate for at least two reasons—first, because he must have led a fascinating life, and, second, because his history illustrates several social and scientific issues of important generality, including the role of amateurs in natural history and the status of Jews in eighteenth-century England. I shall focus this essay on another theme in the category of general messages well displayed: Mendes da Costa's role as a leading collector at the crux of a defining transition in natural history. He practiced at both ends of the passage, from primary concern for weird specimens and star items (the biggest, the most colorful)—the *summum bonum* of the seventeenth-century baroque age, as embodied in the tradition of constructing natural history collections as *Wunderkammern,* or "chambers of curiosities"—to the eighteenth-century passion for order in the classical world of the Enlightenment. Linnaeus's new system acted as a prerequisite for Darwin's revised explanation of causes. But the older love of oddity continued to fan public enthusiasm (and still does so, quite appropriately, today).



Crude analogies: Linnaeus's terms for the features of the clamshell took flak even in the eighteenth century.
Fundamenta Testaceologiae, 1771

Mendes da Costa was an ordinary man in the midst of this great transition. And ordinary people often record patterns of history with maximal fidelity and interest—for Mendes da Costa made no attempt to innovate on a grand scale, and he therefore becomes a standard for his age. In Linnaeus we grasp the thrust of change. From Mendes da Costa we can best understand the fixed beliefs, the impact of novelty introduced by innovators, and, particularly, the intellectual impediments that his age posed to better comprehension of the natural world. We must learn to view these impediments with proper sympathy—not in the old style of condescension for an intellectual childhood to compare with our stunning maturity, but as a set of consistent and powerful beliefs, well suited to the culture of another time, and held by reasonable people with raw intellects at least as good as ours. If we can achieve such fairness and equipoise, the history of science will become the greatest of all scholarly adventures—and also the most utilitarian, for the foibles of the past can only help us to grasp our own equally constraining prejudices.

So ordinary and yet so different! Partly for reasons of self-definition, but mostly from the contumely of others, Jews have lived apart within most Western nations, often with cruel restrictions attached. Emmanuel Mendes da Costa grew up in Britain at an interesting time, probably more favorable than most, for his people.

Jews had dwelled in England from the Norman Conquest until their expulsion under Edward I in 1290. After banishment from Spain in 1492, and from Portugal in 1497, Sephardic Jews (named from the Hebrew word for Spain) dispersed widely, but still could not settle in England. Some small communities of *conversos,* or Marranos (officially converted Jews, but many still practicing their old religion secretly), lived in England from time to time, but when Shakespeare wrote the *Merchant of Venice,* and created the antisemitic character of Shylock, no openly practicing Jews inhabited England. A new group of Marranos began to enter Britain from Rouen in the 1630s. This community, hoping for more toleration from Oliver Cromwell's Protectorate than from the previous monarchy, petitioned for the right to practice their religion openly—and their plea received favorable action in 1656. The restored monarchy of 1660 did not rescind the permission, and a few Jews therefore continued their most tenuous tenancy. They could not, for example, engage in retail trade in London until 1822, and could not sit in Parliament until 1858 (Disraeli was a Christian convert).

As part of this history, very few Jews inhabited England in Mendes da Costa's day—about 2,000 Sephardim by the end of the eighteenth century, and perhaps somewhat more Ashkenazim, or Jews of German and eastern European origin. In a potentially prejudiced society, just a few folks from an alien culture may appear exotic and fascinating, rather than threatening and despised—and the rarity of Jews seemed to work in Mendes da Costa's favor, as he often encountered philosemitism among his noble and gentleman correspondents.

Emmanuel Mendes da Costa was trained in law, but chose to devote himself to natural history. He built a fine collection and published several articles, leading to his election as a fellow of the Royal Society (England's premier association of scientists) in 1747 and to the Society of Antiquities in 1751. But his troubled and shadowy side also surfaced amidst his successes. The *Dictionary of National Biography* remarks: "Although he early obtained the reputation of being one of the best fossilologists at his time . . . his life appears to have been a continual struggle with adversity." He was imprisoned for debt in 1754. After his release the next year, he began to prepare, and finally published in 1757, his major treatise, *The Natural History of Fossils*.

Mendes da Costa received his biggest opportunity in 1763 when he became clerk of the Royal Society, in charge of their collections and library, then in a state of neglect and disrepair. He wrote to a friend in September 1763:

> I immediately proceeded to work, but such was the state of the said libraries and museum, that I am inclined to think the Augean stable was but a type of them [a reference to Hercules' most unpleasant labor, far more taxing than killing the Lernaean Hydra, of clearing thirty years of manure from the stable of Augeas, king of Elis]. . . . After many week's work, amidst the repeated curses of myriads of spiders and other vermin, who had held peaceable possession for a long series of years, I accomplished, so that, thank God, now both libraries and museum are accessible, and in a state fit to be consulted by the curious.

But Mendes da Costa took great joy in the good fortune of his new job. He wrote to another friend:

> Whenever you come to town, pray let me see you. Our museum here, I assure you, has many fine things, and our library is very numerous and scientific. I am very happy in my places, and henceforward my whole life will be devoted to study.

But four years later, in December 1767, he was dismissed for "various acts of dishonesty," arrested at the suit of the Society, and committed to the King's Bench prison, where he remained until 1772. His library and collections were also seized and sold at auction. (I have been unable to discover the charges lodged against Mendes da Costa and can't help wondering about their validity, especially given history's sad pattern of scapegoating Jews and other outsiders.)

Mendes da Costa continued his work under confinement, aided by the support and patronage of several well-placed friends. On January 3, 1770, he wrote to a Dr. Francis Nicholls:

> I received your much esteemed letter, which honors me with an invitation to your house at Epsom, to review some fine minerals you have lately collected in Cornwall. . . . But I am so unfortunate at present as not to be able to embrace the much desired and respected offer you make me; as I am under confinement in this King's Bench. . . . However, the Almighty who had afflicted me with the confinement, has through his mercies granted me the call of my reason, and I apply myself as much as ever, and assiduously to my studies.

Four years later, Nicholls still remembered, and wrote:

> It is with pleasure I hear you are restored to liberty and philosophy; and that you should like to see my collection of Cornish fossils. . . . My son will come down next Sunday morning; so, if you will be at his house in Lincoln's Inn-fields by nine, he will bring you down, and render your journey less tedious.

Science should be chaste and delicate. Ribaldry at times has been passed for wit; but Linnaeus alone passes it for terms of science.

—Emmanuel Mendes da Costa, 1776

Mendes da Costa soldiered on, writing increasingly more obsequious letters in hopes of selling specimens or delivering lectures for a fee. His worst debacle and embarrassment occurred in 1774, when his petition to deliver a series of lectures at Oxford was not only summarily rejected, but scorned with the overt politeness often used by powerful patricians before they squish a plebeian favor-seeker like an insect. Apparently, Mendes da Costa made the mistake of submitting a formal proposal, when he needed to work through channels and secure the verbal permission of the vice-chancellor (the boss of the university). (In any case, I doubt whether a Jewish jailbird would have received such sanction under any circumstances at the time.) Mendes da Costa did finally prevail upon a professor to visit the vice-chancellor, who promptly spurned the idea: "The course of lectures proposed to be read by Mr. Da Costa could not be read here with propriety. I hope the disappointment will sit easy upon Mr. Da Costa." In fact, the rejection weighed most heavily, as Mendes da Costa wrote to the professor:

> I am very certain my attempt has not succeeded by means of some unfriendly and sinister misrepresentations, as well as through mismanagement on my side, for want of proper advice how to proceed. I unluckily had not a friend who chose by a single line to set me right, or inform me what to do. . . . Thus left forlorn, absent from the scene of action, and ignorant how to proceed, I became shipwrecked, and my hopes were blasted.

But Mendes da Costa never gave up. He published his conchology book in 1776 to good notices, rebuilt his collections, kept up his correspondences, and died in reasonable honor.

Throughout this various life, one theme keeps circulating in constancy: Mendes da Costa's Judaism, and the fascination thus inspired among his philosemitic Anglican friends. Mendes da Costa must have become a semiofficial source on Jewish matters for the British intelligentsia, at a time when very few English Jews could have traveled in these circles, neatly balancing enough assimilation to find acceptance with sufficient practice of Judaism to be regarded as authentically exotic. In 1751 a physician inquired of him: "Whether there is extant anywhere a print or drawing, or any account of the dress and arms of a Jewish soldier, or whether the Jewish Soldiers did not wear the same dress as the Roman Soldiers." Mendes da Costa replied that he did not know, since Jewish sources do not permit representation of human images:

> In regard to any drawing, *etc.*, we never permitted any in our books, apparel, *etc.*, it not being agreeable to the religion . . . yet I do not find that drawings were at all used in books, *etc.*, even by the Greeks and Romans.

In 1747, Mendes da Costa had to forego a ducal invitation in order to celebrate the High Holidays. But His (philosemitic) Grace understood very well and hastened to assure poor Mendes da Costa, who greatly feared that he had offended a high potential patron. The Duke's secretary wrote:

> His Grace is very sorry the duties of your religion, which every good man is well attached to, prevent your coming hither just at this time . . . . The Duke being the most humane and the best man living, you need be in no difficulty about your eating, here being all sorts of fish, and every day the greatest variety of what you may feed on without breach of the Law of Moses, unless the lobsters of Chichester should be a temptation

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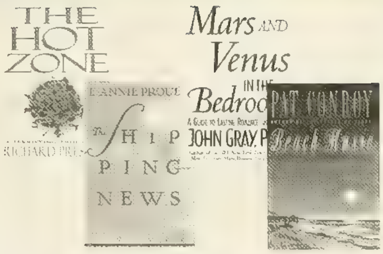

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by which a weaker man might be seduced.

In 1766, Mendes da Costa hears of some Hebrew inscriptions at Canterbury, and he writes to an acquaintance there:

> In a MS of Dr. Plot's dated June 10, 1674, I find this notice: "Ancient inscriptions on ruinous buildings—such as the Hebrew exquisitely written on the old walls of the Castle of Canterbury." Is there such a Hebrew inscription now extant? If there is, can a copy be procured? or can I have permission to employ some Jew (of Canterbury) to copy it, and decypher it?

His friend passed the request to an Anglican who knew Hebrew, for a Jew would not be able to gain access. This scholar wrote directly to Mendes da Costa:

> The Hebrew inscription you inquire after was written on the walls of one of the stone stair-cases in the old castle at Canterbury, in the 13th century, by the captive Jews, during their imprisonment there, and contained some few versicles of the Psalms. . . . It is, I do suppose, no very difficult task to get admittance to this inscription, by any gentleman of the County, or one supported by proper recommendations; but I think they would make great objections to admit a stranger and a Jew to search for it.

Amidst these signs of both philo- and anti-semitism, we also complete the gamut with purely benevolent ignorance. A correspondent writes to Mendes da Costa in 1755, offering payment in goods for services rendered in identifying specimens of natural history: "It is said by most people that Yorkshire hams are very much admired, and if you should think so, will send you some up." The editor appends a telling footnote at this point: "Mr. Knowlton seems not to have recollected that he was writing to a Jew."

Most telling for the history of science, we learn from the correspondence how Mendes da Costa straddled two great sequential worlds of natural history—from the baroque passion for gathering oddities, to the classical urge to order and classify in a single, comprehensive system. The quest for oddities certainly emerges in this offer from a correspondent on December 9, 1749:

> I have some natural curiosities to present you with. . . . I have the tooth, or tusk, of the sea-lion, . . . part of a young elephant's tooth, in the section of which is an iron bullet, which had been shot into it when younger, and the ivory grown over the bullet; a hair-ball, found in the stomach of a calf; and a fossil or two; which shall all find their way to your Cabinet if you think them worthy a place in it.

But Mendes da Costa's own requests mostly record his concern for completion and order. He asks a Jewish friend in Bath to collect as may kinds of fossils as possible, and to send them to his local coffee house—a striking example of different services rendered by public places before the days of home mail delivery:

> In regard to fossils, see if you could get me any *ammonitae*, or snake-stones, as they are vulgarly called, as also impressions of plants on a kind of coal slate, which abound in the collieries. At Lincomb and Walcot are stone quarries which afford very fine petrifactions of shells, etc. Could you procure any of these things, and send me a box full directed to the Bank Coffee-house, I shall cheerfully repay all charges whatsoever.

Mr. Schomberg knew what he wanted in return: "Send me a small pot (of about three or four pounds) of sour-crout, . . . and take care it is well secured, so as not to be broke."

Mendes da Costa straddled two great worlds of natural history—from the baroque passion for gathering oddities to the classical urge to order in a single, comprehensive system.

Over and over again, Mendes da Costa begs his correspondents to pack carefully and label properly:

> Of whatever is collected, let each specimen be carefully wrapped up and numbered, and a catalogue made with answerable numbers to each specimen, wherein specify what it is, what it is vulgarly called, where found, whether in plenty or rare, at what depths, among what other fossil bodies, and all the other curious particulars you can be informed of to elucidate the natural history of them. I beg pardon for troubling you thus, but I am greatly obliged to you for this great piece of friendship.

Mendes da Costa's most assiduous correspondence dates from the 1740s and 1750s as he collects, and beseeches friend to procure, as many "fossils" as possible for his forthcoming, comprehensive treatise, *The Natural History of Fossils*. Following contemporary custom, Mendes da Costa secured subscriptions to this book before publication (a favored fund-raising device for expensive works). His substantial list, published after the preface to his work, includes six bishops and five lords, further testifying to his acceptability among the Anglican upper classes (Mr. Joseph Harris, "assay master of the Tower," also signed on for a copy).

Mendes da Costa published a first substantial volume of his treatise in 1757, but never proceeded any further. This work is, nonetheless, his masterpiece—and a superb example of the passion for fully comprehensive order that so motivated eighteenth-century natural history. In Mendes da Costa's time, "fossil" (from the past tense of the Latin *fodere*, "to dig up") referred to any natural object taken from the earth, not only to the remains of organisms. In fact, rocks and minerals represented the quintessential fossils of eighteenth-century terminology, since they belong to the mineral kingdom—as natural products of the earth—whereas remains of ancient plants and animals must be introduced into rocks from the animal and vegetable kingdoms. Thus, the bones, shells, and leaves, now exclusively honored with the term "fossil," were known as "extraneous fossils" in the eighteenth century, while rocks and minerals represented essential fossils. Mendes da Costa therefore intended to cover all products of geology in his treatise—rocks, minerals, and remains of ancient organisms. But his first and only volume did not proceed beyond rocks and earths. (If he had completed the full design, and had followed the usual classifications of his time, he would probably have written a second volume on minerals and crystals, and a third on remains of organisms.)

Despite Mendes da Costa's disgust at Linnaeus's sexual terminology for clams, the great Swedish naturalist reigned as the prince of order. We know that Linnaeus's binomial system persists in largely unaltered form as the basis for giving scientific names to organisms today. This system has served us so well (despite recognized limitations) that we forget the fallacies of its original overextended application—an amnesia also abetted by our tendency to view the history of science as a list of growing successes, with errors buried into a conventional metaphor: "the ash-heap of history."

But Linnaeus's original application of binomial nomenclature suffered under the primary eighteenth-century fallacy of too much grandiosity in attempting to encompass all possible kinds of natural diversity in one system of classification. For Linnaeus didn't apply the binomial system only to plants and animals (where it works quite well), but also, in essentially unaltered form, to minerals, and even, in his *Genera Morborum* of 1763, to diseases, which he grouped by their symptoms into classes, orders, and genera.

The Linnaean system implies a definite geometry for the ordering of objects and therefore only works when the causes of order produce results conforming with this geometry. Consider two essential properties: First, the Linnaean system is hierarchical. The basic units (species) are grouped into genera, genera into families, families into orders, and so on. This scheme implies a treelike topology with the largest unit (say, the kingdom Animalia) as a single trunk; middle units as

Please turn to page 62

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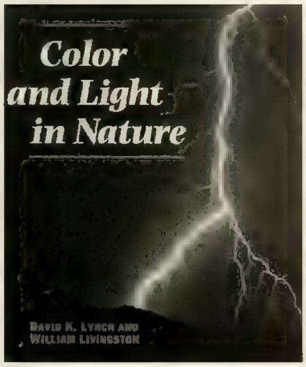

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The Great Leap Down Under

Did the good life in Australasia propel humans into modernity?

by Timothy Flannery

Competition between species is a powerful evolutionary force. Species that compete for similar resources can also limit their competitors' distribution and numbers. In relatively stable, highly coevolved ecosystems, it is difficult for any one species to get the jump on another: as one species evolves strategies for avoiding predators and parasites or for more efficiently gathering its own food, others adapt to cope with the latest innovations. In such ecosystems, species do not make great leaps—only small steps to which other species quickly accommodate themselves. Biologists have called this competitive treadmill the Red Queen hypothesis after the character in Lewis Carroll's *Through the Looking Glass*. Like species in a coevolved ecosystem, the Red Queen was famous for running simply to stay in the same place.

But what happens when a species is suddenly released from competition? The numerous animals and plants translocated by people around the world provide splendid examples. If the species is suited to its new home, it usually experiences a rapid population increase. Once local resources are depleted, its numbers fall. Eventually it comes into balance with an altered ecosystem. When red deer were introduced into New Zealand, they increased rapidly (25 to 30 percent per year) and were larger and healthier than the parent stock. Thirty years later, numbers had peaked and soon thereafter began to decline. Today, a smaller population of smaller deer remain, feeding upon a dramatically altered and less nutritious pasture.

Could some scenario of ecological release have applied to early humans? And could it explain what biologist Jared Diamond has called the great leap forward—the transformation that occurred in many places around the world some 40,000 years ago, as humans began to make more elaborate tools, trade widely, create art, expand their numbers, and (some evidence suggests) develop sophisticated systems of belief? I suggest that when humans first colonized Australasia, they experienced just such a release and that this may have caused the great leap.

Consider the Afro-Eurasian ecosystem in which humans evolved, hunting and gathering for more than a million years. As humans gradually became better predators, many prey species just as gradually adjusted. The balance did not shift dramatically, so little more in the way of resources was available to people 60,000 years ago than half a million years ago.

Carnivores doubtless limited the human niche. It would have been a foolish and short-lived hominid that entered dense thickets of vegetation where large felids and other large carnivores lived.

Competition with other primates would likewise have limited human activity. Chimpanzees, orangutans, and other primates outcompeted humans for resources in rain forests. On the savanna, baboons or other herbivores were often the first to reach edible plants or grass seeds that humans might otherwise have used.

What did early humans do to break free of such ecological constraints? For a million years, hominids had looked across the twenty-mile-wide strait between Bali and Lombok upon the uninhabited lands east of Bali. Then, sometime between 40,000 and 60,000 years ago, either by accident or design, someone crossed that barrier in some kind of watercraft, resulting in the first human footfall on a land that had evolved without humans.

The first voyagers to Lombok would have quickly realized that this was a very different place from the one they had just left. The Lombok Strait marks Wallace's line, the line that divides Asian-derived species of animals from Australasian ones. The mud flats and reefs would have been strewn with mollusks and crabs that had never been harvested by a primate, while the seas were filled with fish that had never been fished.

Just as important, potential inland prey species—such as pygmy elephants (*Stegodon* spp.), birds, bats, and large rats—would have abounded. This very distinctive fauna differed dramatically from the much more diverse assemblages of large mammals present on Bali and Java. And none of these animals had ever seen a large mammalian predator before.

For the first time ever, humans, whose skills had been honed in a million-year-long arms race with Asia's biggest and best, could have a profound impact on an entire biota. This must have had a considerable psychological effect. Before, success in the hunt was highly uncertain. In the new land, every hunt would have been successful. Without predators and surrounded by naive prey, people became—in a sense—gods, all-powerful beings in a land of plenty. People were well-fed and had much leisure time during this initial phase. They probably lived in larger aggregations than ever possible before.

In this land without apparent ecological limits, human numbers would have increased rapidly. The carrying capacity of an island such as Lombok may have been extraordinary, for humans could co-opt virtually every resource suitable for them. Back in Bali or Java, resources went toward supporting thousands of other species, including such big energy users as tigers, leopards, elephants, and rhinos.

The resources of small islands such as Lombok could not last indefinitely, however, and finally the crunch had to come. But perhaps even this acted to propel the people toward taking the great leap. As the last of the pygmy elephants (possibly the only large herbivores present on the island) were eaten, fire supported by the buildup of uneaten vegetation was probably already ravaging the mountain slopes. If the human impact on Pacific islands is any guide, erosion washed soil into the fringing lagoons and swamps of the lowlands, smothering rich marine resources but creating a fertile coastal plain.

With the collapse of animal resources, people concentrated on plants, many of which were familiar. In contrast to animals, many plants had long ago jumped Wallace's line, colonizing disturbed and newly created habitats. Pioneer species such as wild bananas, taro, yams, and sug-

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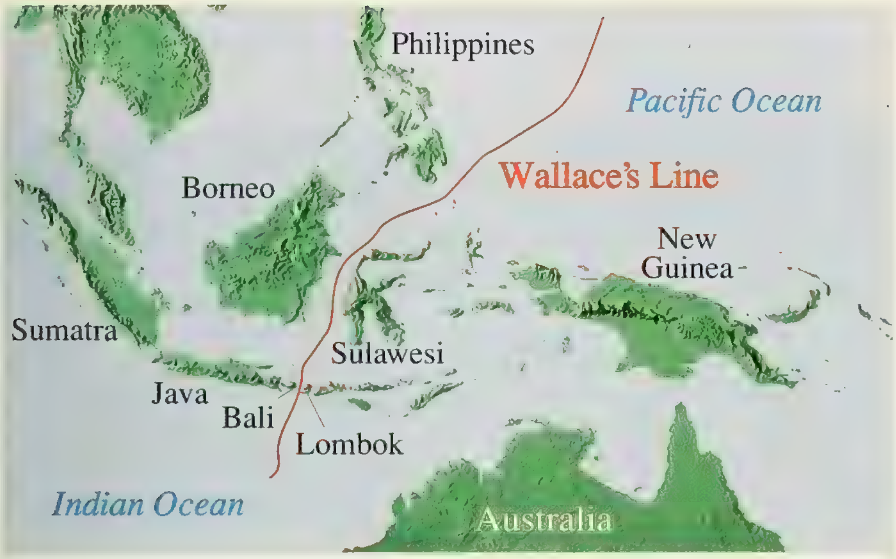
Adapted from *The Future Eaters*, by Timothy Flannery, published by George Braziller, Inc.



The first humans to move from Bali to Lombok crossed a biogeographical frontier—first recognized by Alfred Russel Wallace—separating Asian-derived organisms from those of the unique Australasian ecosystem.
Peggy Conversano; adapted from Mountain High Maps. ©1993 by Digital Wisdom, Inc.

arcane would have populated the large areas of rich soil on the newborn coastal plain. With a large and growing human population dependent upon such resources, it seems likely that our ancestors quickly developed any previous rudimentary knowledge of agriculture and plant selection to increase yields.

Along with these inducements to experiment with agriculture, the increase in population probably sharpened competition between groups of humans. Communities may have developed social structures that enhanced their ability to process and distribute food, if not to defend and take resources from others. They may also have been prompted to develop ingenious technologies or behaviors to gain access to as-yet-untapped resources.

The conditions conducive to development of the great leap endured for thousands of years, for Australasia is a great string of islands, almost every one within sight of another or joined at times of low sea level. It stretches for more than 3,000 miles to the east, and south as far as the southern Solomon Islands and Tasmania. As people colonized island after island, they developed seaworthy craft.

If the great leap forward did take place in island Southeast Asia, then the ideas and technologies to which it gave rise must have been carried back to the great Afro-Eurasian homeland of humanity by 40,000 years ago. Innovations that led to the great leap forward may have been passed from one group to the next peacefully, much the way that ideas about mass production have spread around the world in the twentieth century. Groups that possessed such knowledge would certainly have been able to increase their population and thus gain a competitive advantage.

Whatever the case, an understanding of the factors that powered the first great leap forward is critical to humans living today. For we are in the middle of another leap—into the information age. The first great leap forward brought us from a time when humans were one relatively rare species among a vast assemblage of large mammals in Afro-Eurasia to a time when we dominate the globe. But it was only achieved at the cost of the destruction of whole biotas, and it established the pattern of resource mining that has been the hallmark of modern humanity. We cannot afford to leap at such expense again. ☐

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Child's Play

A scientist and a panel of pint-sized consultants review natural history toys

by Howard Topoff

Scientists and children have a lot in common. Although adults by standards of size and reproductive ability, scientists never surrender a childlike peculiarity of incessant questioning and fascination with the natural world. And like any kid, scientists find these inquisitive traits especially useful for playing with the toys, games, and puzzles that engulf their family lives during the holiday season.

During the past several months, while other Museum scientists trekked across scorched deserts probing for new fossils, I've been on an even more unusual field assignment: exploring the remote corners of air-conditioned shopping malls, searching for toys and games with a natural history theme. My goal was to blend the gift-giving spirit and fun of Father Christmas (Santa Claus) with the educational legacy of the father of evolutionary biology (Charles Darwin).

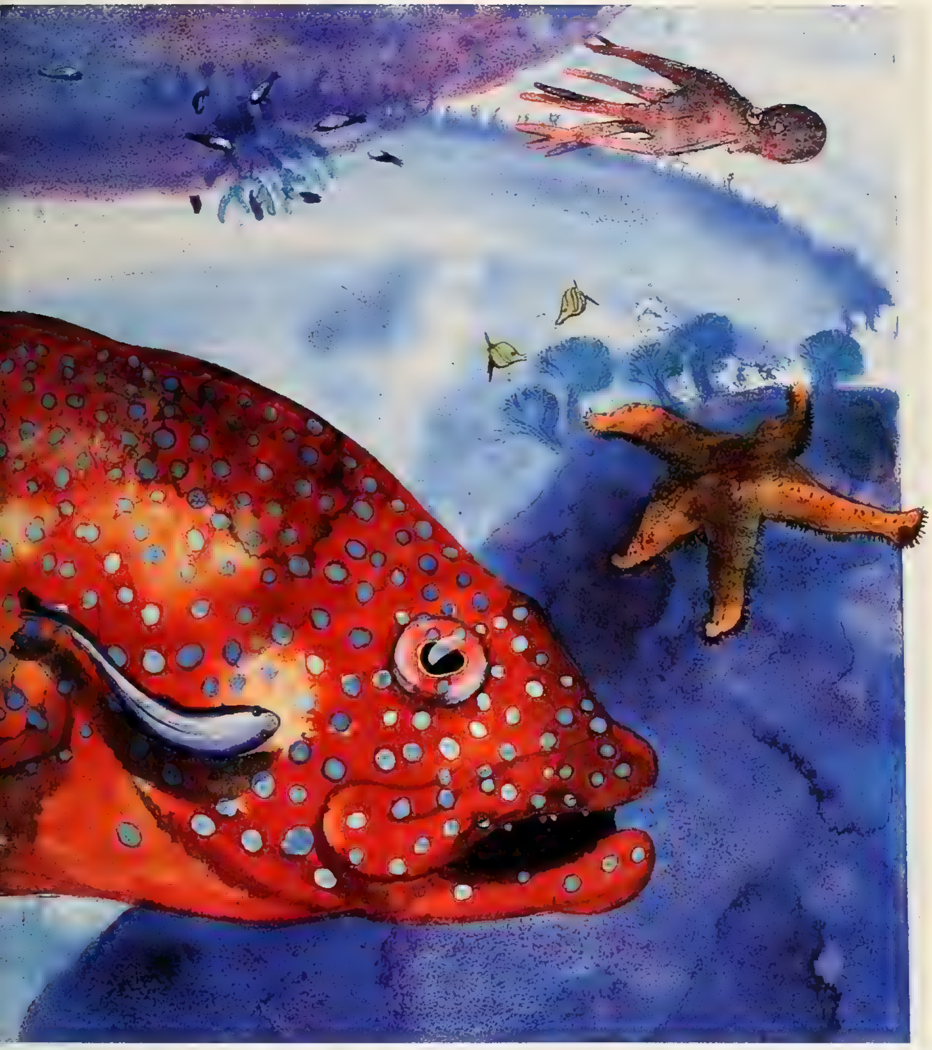
To be honest, I used to find megamalls boring. Even more than television, these retail cities have contributed to the homogenization of American culture. But my interest in malls has been rekindled since a new breed of stores—with names like Imaginarium, Whiz Kids, the Nature Company, Teacher's Tools, and the Knowledge Store—infiltrated America's shopping heartland. These retail chains specialize in educational games and toys. Books on the care of pond turtles replace armies of Ninja Turtles; and hands-on kits demonstrating how caterpillars turn into butterflies supplant little plastic tanks that turn into laser-shooting dragons.

After filling my cart with an assortment of natural history toys and games, I assembled a team of six experts to help me assess them for *Natural History*'s readers. The credentials of the evaluators were carefully screened: they had to be either girls or boys, and they had to have at least four years experience being a kid. I offer here the results of our hard work: a holiday sampler of activities that are fun and that add to our understanding of the natural world. Each was ranked on a scale of 1 (rapid extinction would be desirable) to 4 (a must buy). Happy shopping!

The Eyes Have It

OPTICAL ILLUSIONS. *The Nature Company. $19.95. Recommended ages: 11 and up. Rating: 4*

One rainy afternoon I gathered all the youngsters in our group of judges and showed them a picture of the Giraffe Bank. A venerable institution of the savanna, it offers a wide range of financial services, including ATM (automated tick-bird machines). The picture shows two customers, a mother giraffe and her son, waiting patiently for a tall teller. "Which is the mother?" I asked. "The larger one in the back," everyone agreed. So I handed out a small ruler and asked the kids to measure the giraffes. You should have



" 'But nothing can see me when I hide,' the coral cod tells her, as it slips under a ledge and disappears."
From Swim for Cover: Adventure on the Coral Reef, *by Sue Vyner; illustrations by Tim Vyner. Crown Publishers, Inc., $15.*

seen the look on their faces when they discovered that the giraffes were identical in size. Even more amazing was the realization that knowing that the two animals are the same size doesn't alter the impression that the one in the rear of the bank is indeed larger. What's going on here?

The illusion works because all the perceptual cues combine to trick your brain into "thinking" that one giraffe is considerably farther away. But the images on your eyes' retinas are identical. So how, your brain asks, can one object be farther away than another and still cast the same-sized image on the eye? Easy! The second object must be larger.

Welcome to Optical Illusions, one of the Nature Company's Cigar Box Series of hands-on scientific exploration kits. Optical Illusions presents a playful insight into the psychological world of visual perception. The box is stuffed with mirrors, prisms, kaleidoscopes, fact sheets, and just about everything else needed to probe the world of light and sight.

Our next surprise came as we explored mirror images. Like most people, the children thought a mirror image is an identical reflection of an object. So I put the mirror in front of a girl's face and asked her to close her left eye. "Which eye is your reflection closing?" I asked. "The left eye, of course," she answered. "Look again," I insisted. "Oh wow!" she shouted, moving her face closer to the mirror, "It's the right eye." Of course, none of the other children believed this until each had a try with the mirror (if any readers feel an uncontrollable urge to drop the magazine and head for the bathroom mirror to check this out, go ahead. I'll wait.)

Optical Illusions is chock full of illusions, delusions, and deceptions—all challenging the notion that seeing is believing. After you buy it, perhaps you should check to see that it's really in the bag.

Good Heavens

Our Solar System. *Frank Schaffer Publications, Inc. $12.95. Recommended ages: 4 and up. Rating: 3*

I'm convinced that there is an inverse relationship between the size of objects scientists study and the size of the equipment used. To explore the social behavior of a ninety-foot-long blue whale, a pair of binoculars, a video camera, and a notebook are adequate tools. But to understand how subatomic particles interact, you have to coax them to meet with a superconducting supercollider that takes up a substantial portion of the state of Texas.

This principle has a corollary for children's toys, especially jigsaw puzzles: small hands, combined with fledgling motor skills, require extra-large pieces. Frank Schaffer Publications has come to the rescue with a series of five-foot-long puzzles. The average piece is almost five inches across, and the puzzles are assembled on the floor, which greatly adds to the fun. The pictures are challenging without being frustrating to a child (or even an adult): no machines filled with bubble gum balls and no polar bears in a blizzard. Instead, Schaffer has put together six colorful panoramas, covering a variety of natural history topics: Rain Forest, Our Solar System, Endangered Animals, The Forest, The Pond, and A World Of Dinosaurs.

Our team of critics assembled Our Solar System, which depicts the sun and its nine principal orbiting planets. Pluto, the outermost planet, is five feet from the sun. If drawn to scale, the puzzle would have to be slightly more than sixteen feet long. We always knew which pieces we were hunting for because we knew where the planets were in relation to the sun. The hunt quickly became a game of intergalactic banter, such as: "Can anyone find a ring of Saturn's?" Or, "No, that small thing is Pluto. I'm looking for the earth's moon."

We knew this was a good educational toy because the kids had many questions after the puzzle was completed. Topics included the heat of the sun, the distances of the planets, and what planets are made of.

Unfortunately, the puzzle comes with little documentation, so unless you have a budding astronomer in your family, you'll probably have to find another source to answer most questions. To be fair, scientific instruction is not the primary goal of Schaffer's puzzles. They are designed to build concentration, develop problem-solving skills, strengthen visual discrimination, and enhance eye–hand coordination. Although the puzzles admirably cultivate these abilities, a booklet containing a few pages of basic facts would clearly be of value to most parents.

And what can you do with a five-foot-long puzzle of the solar system after it's completed? One child took off her shoes and turned the glossy-surfaced puzzle into a physical fitness platform, sliding sideways from the sun to Pluto and back. Finally, all the kids suggested taking the puzzle to school to let their classmates assemble it. What a neat idea.

The Antics of Ants

Uncle Milton's Ant Farm. *Uncle Milton Industries. $9.95. Recommended ages: 8 and up. Rating: 2*

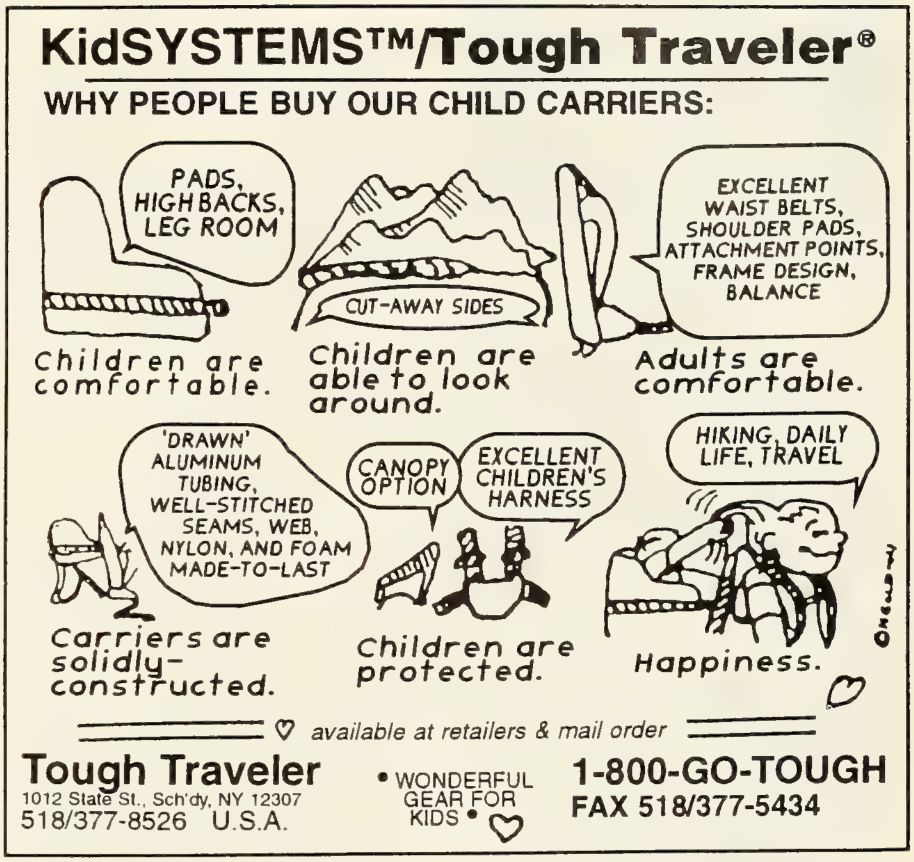
Nineteen fifty-four was quite a year. Rocky Marciano kayoed Ezzard Charles, and my sixth-grade teacher was fired for being a Communist sympathizer. And while adults throughout the country heralded the launching of the *Nautilus*—the first atomic-powered submarine—children of all ages were preoccupied with an event that would prove to be far more durable: the introduction of Uncle Milton's Ant Farm. With all the high-tech gizmos generated during the past forty-one

"Harvest mice . . . build their summer nests early in the season among tall grasses." From Kenneth Lilly's Animals: Wildlife Around the World, *by Joyce Pope; illustrations by Kenneth Lilly. Candlewick Press, $12.99.*

years, Uncle Milton's Ant Farm remains essentially unchanged: a vertical plastic enclosure, powered not by six-volt batteries but by six-legged creatures.

Each Uncle Milton's Ant Farm includes a certificate for one shipment of ants, at no extra charge. Now, there are approximately 8,000 species of ants in the world, and their diversity includes predatory army ants, fungus-growing ants, and even slave-making ants (which kidnap the young of other species to do their work for them). Unfortunately, federal law prohibits the shipment of queen ants (to avoid introducing species into new habitats), so all we received were about two dozen sterile workers. And without larvae to feed, they were sluggish and didn't eat very much. Our child judges also weren't thrilled when I called their attention to the statement emblazoned on the "Ant Watcher's Manual," which comes with the farm: "Never handle or touch ants! They can bite." It's not their bite that concerns me. It's their sting! The workers that come with the ant farm are harvester ants of the genus *Pogonomyrmex*, and their sting is comparable to that of a honey bee.

Even more disappointing were the manual's answers to the most frequently asked questions about ants. On one page we are informed (correctly) that all workers are females. On the next page, however, the ants are given a sex change, and we are erroneously told that when one ant



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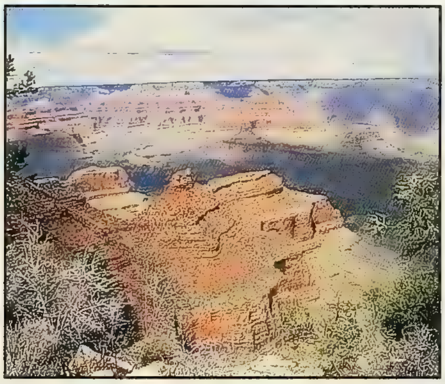

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wants to communicate with another, *he* taps it on the head with *his* feelers. Things go from merely incorrect to downright absurd later in the manual when we "learn" that ants sleep, play, have a board of directors, hold regular meetings, and even wash their faces with their hands.

So is there anything good to report about Uncle Milton's Ant Farm? In a word, yes. Our farm came with a Bonus Pack, a seventy-one-page book about ants, written by Millicent Selsam, author of many superb children's science books. Unlike Uncle Milton's manual, this book is accurate, nicely illustrated, and provides an excellent overview of the biology and behavior of ants. My advice: keep the book, chuck the manual. After about a week, we also discarded the ants that arrived by mail and went on our own ant-collecting trip. This not only added to the fun, but after turning over a few rocks, we had an intact ant colony, complete with queen and brood. Within hours we were treated to a wide range of insect social behavior: communal digging, foraging, mutual feeding and grooming, and even egg laying by the queen. We observed, took notes, read Selsam's book, and talked about animal behavior. Wow! We felt like scientists.

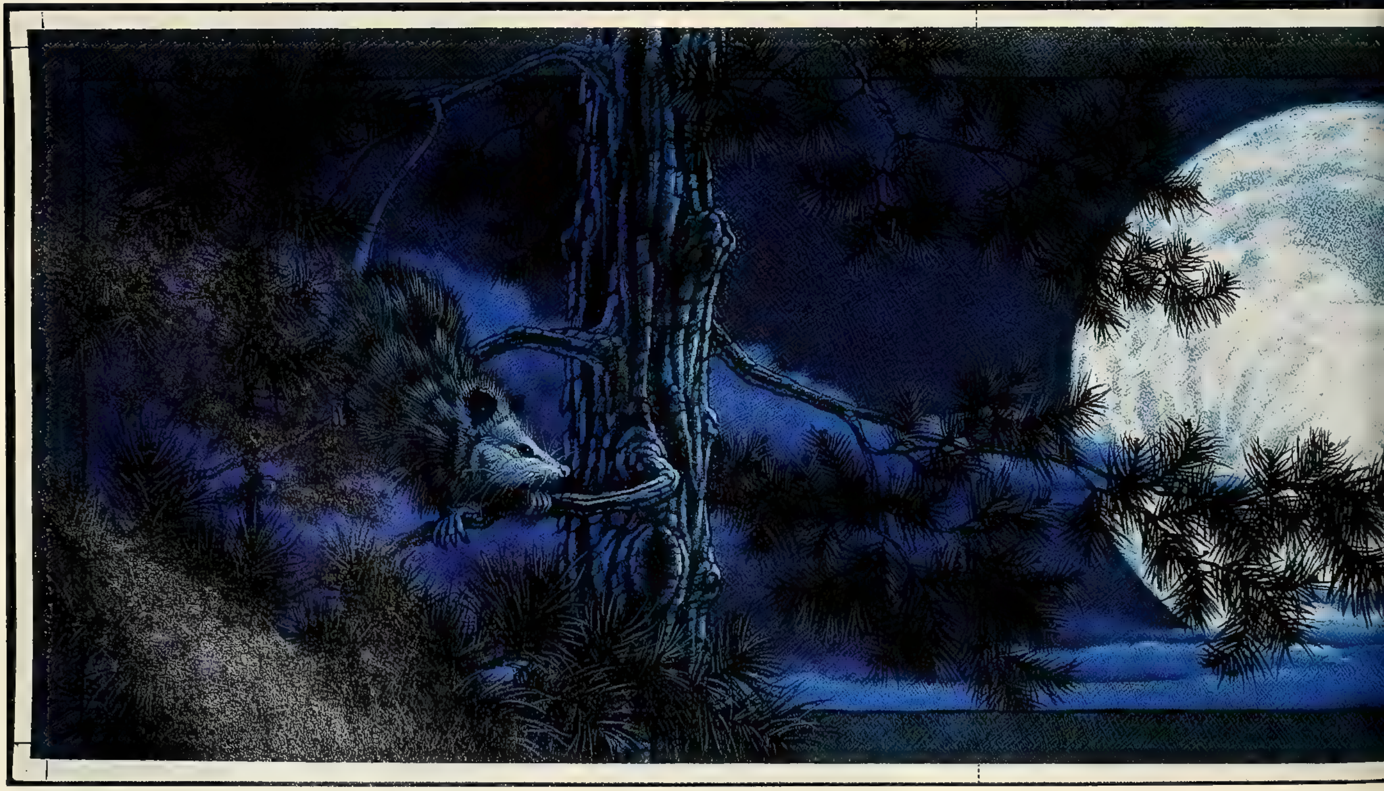
Fortunately, Uncle Milton does offer an important option. If you decide to collect your own ants, the certificate can be redeemed for a magnifying glass. It's not a very good one, but it's far better than the ants that arrive by mail. We all agree that any kid receiving Uncle Milton's Ant Farm as a gift should send for the magnifying glass, go out in the field, and have fun digging in the dirt.

Flower Power

TREE RINGS; LEAVES; WILDFLOWERS. *Educational Insights. $17.95. Recommended ages: 9 and up. Rating: 3½*

As far as kids are concerned, when it comes to toys, dinosaurs still rule the earth. With virtually all of our attention focused on animals, we tend to ignore an entire kingdom of living organisms—the plants. In every habitat, without plants' ability to create organic matter through photosynthesis, no dinosaurs (or any other animals) could exist. But botany is virtually ignored during gift-giving time. The problem is even worse for boys, because of the unfortunate notion that beasts are macho, flowers aren't. So how can we introduce a generation of children to the importance of plants in the world's ecosystems? For starters, we recommend Tree Rings; Leaves; and Wild Flowers—three hands-on nature kits from Educational Insights (the same company that markets the award-winning electronic game GeoSafari). The boys and girls in our team cooperated on all three projects.

The principal ingredient of Tree Rings is a cross section of a real Ponderosa pine tree. The kit includes a package of triangular paper pennants, push pins, and a magnifying glass. For our first activity, we used the tree sample to chronicle important dates in our lives: we each wrote our name and birth date on a flag. Using the magnifying glass, we counted the tree rings, starting from the outer bark, and pushed our pinned flags into their proper rings. To my horror, my pin wound up only two rings from the center of the tree. Although the tree was only fifty-six years old, that pin confirmed the kids' impression that I was as old as creation itself. I

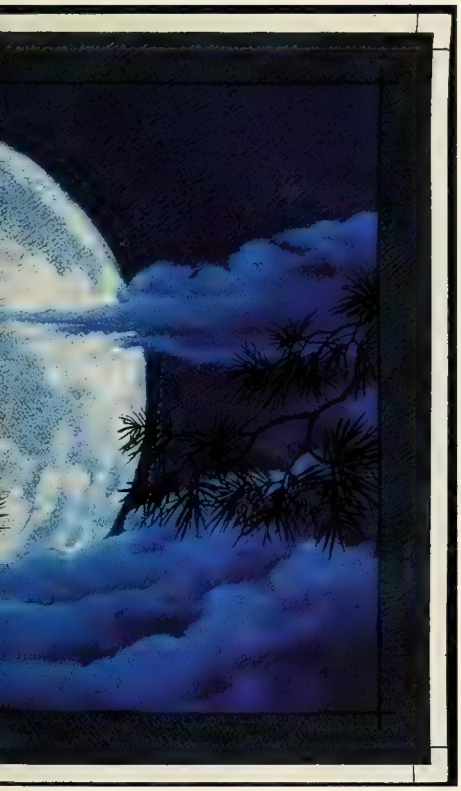


decided I didn't like this game after all.

After trying to convince the kids (or perhaps myself) that I was not born in the Olduvai Gorge (and had never dated Lucy), we turned our attention to the tree rings. Two things were obvious. First, each ring had what the kids called "white and dark meat." Consulting the superb booklet that comes with the kit, we learned that the light sections are caused by rapid growth of the tree in the spring, while the darker areas reflect a reduced growth rate during late summer. The rings also differ in their overall width, representing years of adequate water (wide rings) and years of drought (thin rings.)

While one group of kids was busy with Tree Rings, two others were sent out to the field on a different mission: to collect botanical samples for the other kits: Leaves and Wildflowers. Both include samples of pressed specimens, neatly glued to a paper backing and protected inside a zippered plastic bag. The principal tool in each of these kits is a plant press. To use the press, we placed a freshly collected leaf or flower between two pieces of cardboard. We continued to sandwich each specimen until the press was full. Next, we placed the stack between the wooden frames and compacted the entire bundle by tightening two buckled straps. After a week, we opened the press, glued our specimens to paper backing, labeled them, and sealed them in plastic bags.

It was very gratifying to see a group of children turn their exceptional powers of observation and curiosity on what were formerly considered such mundane objects. Why do the veins in some leaves run parallel to one another, while the veins of others form a branching pattern? What accounts for the different shapes of leaves, sometimes even on the same tree? Do flowers have both male and female parts or are they like people, with separate boy and girl flowers? These are only a few of the many topics raised by the kids as we collected and processed the botanical specimens for our rapidly growing collection. And like Tree Rings, these two kits also include a fact-filled book of hands-on projects, puzzles, and quizzes. On the back of each box, printed like the Surgeon General's warning on a pack of cigarettes, is the statement, "This is not a toy." Well,



"Did you sense Grandmother Moon guiding you home again?" From Did You Hear the Wind Sing Your Name? An Oneida Song of Spring, *by Sandra De Coteau Orie; illustrations by Christopher Canyon. Walker and Company, $14.95.*

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judging from the fun our gang had exploring the world of botany, they could have fooled us.

Face Off

ANIMAL FACES. *Dutton Children's Books. $17.99. Recommended ages: 3 and up. Rating: 3*

Ever have one of those days when you just don't feel like yourself? Well, Dutton Books has a face lift for you. *Animal Faces* is a compilation of fifteen colorful punch-out masks, just perfect for a party. The publisher calls it a book, but our critics say it's a toy. Want to be a monkey's uncle? The African mandrill is for you. Still haven't recovered from *The Lion King*? *Hakuna matata*! Just transform yourself into the king of the beasts. Want to scare the pants off your friends? A large-eared bat should do the trick. And I can't think of a better way to gain a little respect when you enter the room than by looking like a giant stinging hornet.

Elephants, pigs, frogs, zebras, foxes—take your pick. Each is absolutely beautiful and requires but a few minutes to assemble. Pop out the two holes on the sides, insert a string or (better yet) a piece of elastic, knot or tape the ends, and poof—instant beast. Here's the plan. First, invite fifteen kids over on your birthday (you might want to check with your parents). Next, find out who gets which mask. On the inside of each mask is a brief description of the natural history of the animal. The mask goes to whoever knows the correct answer. For example: "I am very small. I have tiny hands to hold things. I nibble on lots of things. People aren't happy to have me in their houses. If I am disturbed, I squeak." One kid was sure he knew the answer. "My baby brother," he shouted. Nice try, but the correct answer is a mouse.

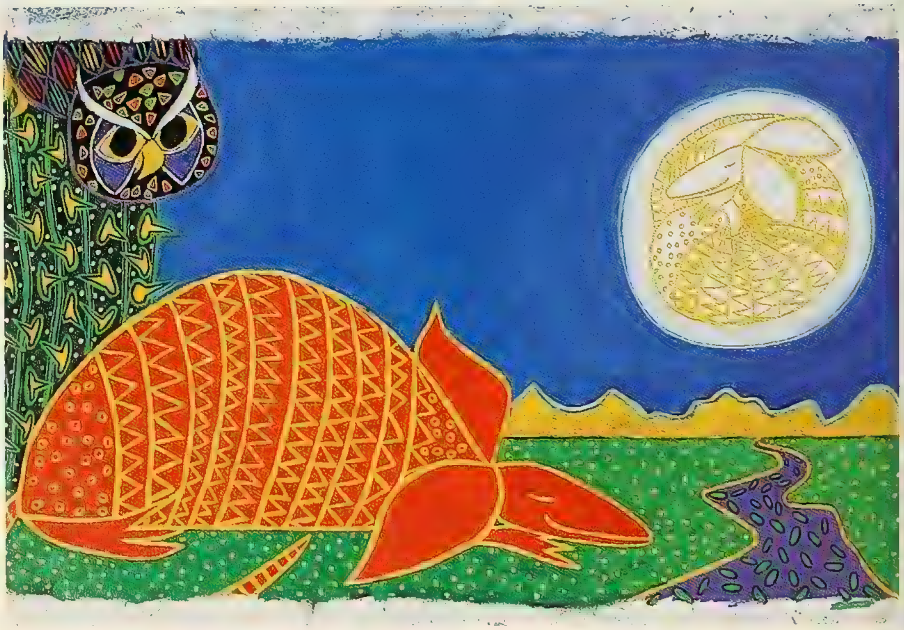
Creature Features

FOLKMANIS HAND PUPPETS. *$3.50 (for a small honey bee) to $50 (for a giant bullfrog). Recommended ages: 3 and up. Rating: 4*

"Hey kids, what time is it?" yelled Buffalo Bob. "It's Howdy Doody time," bellowed the kids in the peanut gallery. This is how my generation was introduced to the magical world of puppets. Today's children are enthralled by a more sophisticated cadre of puppets, such as the ever growing Muppet family. Of course, the puppets of the nineties aren't content with mere entertainment. Reading, writing, and social skills are also their mission.

The folks at Folkmanis, Inc., of Emeryville, California, have gone back to basics: producing hand and finger puppets that are soft, authentic, and just plain beautiful. Sure, their inventory includes the old favorites—lambs, rabbits, bears, and even a not-so-scary skunk—but their phylogenetic tree is a testament to biodiversity. After all, when was the last time you slipped your hand into a cuddly, two-foot-long stingray puppet? Or better yet, a three-foot-long rattlesnake? Perhaps, like me, you prefer your creatures without backbones. Choices still abound, including a praying mantis, cockroach, hermit crab, and firefly. In all, I counted well over a hundred species in their catalog. These exquisite hand puppets are recommended for children ages four and up. And indeed four is typically the minimum age for children to have the motor skills and imagination for putting on entertaining and goofy productions. But not so fast. These puppets come in a dazzling array of colors and textures. The ant is glossy black and feels like silk against the skin. The tarantula is a bit more tousled but still has a warm, cuddly feeling. So in the hands of a parent, these puppets can provide delightful visual and tactile experiences even for infants. The auditory experience, of course, has to be provided by the puppeteer.

Finally, we had to decide what show to produce with our puppets. I suggested *Gone with the Wind*, but unfortunately the kids didn't think a show about a blustery storm would be too exciting, so we opted instead for the *Wizard of Oz*. Well, at least I scored a partial victory. My tarantula got to play the part of the wizard. ☐



"As Ray closed his eyes in sleep, the moon rose again in his dreams. It seemed to be a great shining armadillo." From ARMADILLO RAY, *by John Beifuss; illustrations by Peggy Turley. Chronicle Books, $13.95.*

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The Wombat Digs In

Pressed close to their limits, these burrowing Australian marsupials survive on next to nothing

by Perry S. Barboza

Lying chest down at the burrow entrance, I realized that my position was indefensible should the unseen resident take umbrage at my inspection. When scuffling sounds and low growls emanated from the depths, a sudden premonition of bared teeth emerging from the darkness propelled me to my feet. Although a close relative of the koala, this animal did not fit the stereotype of the cuddly Australian marsupial; despite the common wombat's appealingly rotund form, it has plenty of muscle and sharp incisors and is neither slow nor indecisive about using them.

Wombats rarely show themselves above ground during the day, and this was no exception. I was pleased, however, to hear the rumblings from within the burrow. The sounds confirmed that at least one of the elusive animals was in residence, and I needed to capture about sixteen wombats for my research on their nutritional requirements. Diet, I suspected, was one of the keys to their continued survival in a changing landscape.

> Weighing in at as much as 100 pounds, common wombats are about as large as a burrowing animal can get.

Until Europeans introduced livestock some 200 years ago, kangaroos and wombats were the principal grazers in Australia. These marsupials reached their zenith some 30,000 years ago, when a wetter climate supported many large species, and wombats the size of cattle roamed the grasslands. With the gradual drying of the Australian climate during the Pleistocene, wombats evolved into burrowers.

When wombats emerge at night to feed, they are vulnerable to domestic dogs and native dingoes, but below ground they are invincible. Weighing in at as much as 100 pounds, common wombats are about as large as a burrowing animal can get; wider tunnels to accommodate a bigger animal would increase the danger of collapse. Well adapted to the subterranean lifestyle, their mass is concentrated in a cylindrical, muscular torso. Equipped with stubby legs and broad feet with claws, wombats can excavate several feet of tunnel per night. Within the confines of its burrow, the wombat uses its bony lower back as a shield. Shoving backward with its powerful hind legs, the animal can block attackers (including other wombats). Dogs or other predators entering a burrow for a prospective meal of wombat can wind up being smothered at the end of a blind tunnel by their recalcitrant prey.

The greatest threat to wombats, as with most other species, is humans. While Aborigines hunted wombats for their meat and skin, European farmers have long viewed them as pests and killed them because they damage crops and undermine fences built to exclude livestock and the far more destructive rabbits. For most of this century, Australian law encouraged the eradication of wombats, but now all species of wombats are protected, and hunting is restricted to controlled culls. Unfortunately, many wombats, especially those seeking new territories, are killed by automobiles. Others fall victim to housing developments, which consume large swaths of pastureland in the temperate south.

In the remaining pastures, wombats must compete for food with introduced herbivores such as rabbits and sheep. Nevertheless, three species persist. The common wombat inhabits woodlands and shrublands of the temperate regions of southeastern Australia and Tasmania. The other two species, the southern and the northern hairy-nosed wombats, both dwell in semiarid habitats and have not fared as well. The northern species is restricted to one small colony in central Queensland, making it the rarest Australian marsupial.

In the moderately wet spring of the temperate regions, the common wombat's staple diet of green grass is high in protein and low in fiber, but this changes dramatically as the dry season approaches. The grass goes to seed and dries out, leaving only fibrous blades with little protein. The situation is worse for hairy-nosed wombats, which live in the semiarid plains; frequent droughts and low rainfall result in brief, unreliable periods of pasture growth.

How can wombats persist and even thrive on such poor graze? Under the same conditions, kangaroos can roam widely, while domestic livestock are given supplemental feed and water or removed from the range. But the wombats' underground lifestyle limits their mobility; they cannot easily abandon their warrens of tunnels to move to distant, greener pastures. In my research, conducted with Ian Hume, who now heads the University of Sydney's Biology Department, I hoped to learn how wombats managed to fare so well compared with kangaroos and sheep, which would perish if restricted to the same poor pastures. Such knowledge has become increasingly important for understanding why some species thrive while others decline in ecosystems altered by humans.

To capture the wombats I needed, I was counting on the animals to walk into cage traps as they left their burrows at night to graze. In spite of all their growling protestations, however, I discovered that the wombats were more likely to wait out a siege than to risk capture. In many cases, they simply waited a day or two before digging around the trap or opening a new exit. Large burrows may shelter more than one wombat in a series of tunnels and resting chambers that extend more than 100 feet and descend more than six feet underground. My attempts to block alternate exits and fortify cages with large rocks were frequently foiled by these master excavators. With some persistence, my assistants and I eventually acquired a colony of sixteen wombats, with an equal number of both common and southern hairy-nosed wombats, some from the wild and some from zoos.

We set the wombats up in enclosures in order to monitor their food intake. By building their burrowlike shelters on concrete floors above ground, we prevented them from digging their way out. The wild wombats soon grew accustomed to us in their new surroundings and often assumed their most relaxed sleeping posture—on their backs with legs sprawled. At rest, their shallow breathing was almost imperceptible, and casual observers sometimes thought they were dead. Closer inspection usually roused a wombat, which would spring to its feet, breathing vigorously. Both wombat and observer soon recovered their composure after these unexpected resurrections.

Like any grazing animal, wombats grind their food well, breaking up plant cells and releasing any starches and proteins they contain. This portion of their diet is digested and absorbed in the stomach and the small intestine. The remainder, the fibrous cell walls, can be digested only with the help of gut microbes that can break down the tough cellulose. This fermentation occurs in the wombat's colon, or hindgut, which is the largest section of the animal's digestive tract, and the nutrients released by bacterial action provide up to one-third of the wombat's energy intake. The wombat's healthy gut capacity (up to 33 percent greater than that of herbivores of similar size) allows for slow and thorough fermentation of fiber, as it does in grazing animals much larger than wombats. But the wombat's digestive system is more efficient than those of kangaroos, sheep, and cattle. In these animals, food passes through the fermentation process before it enters the small intestine, so some of the energy in nonfibrous, easily digested plant components is lost to the bacteria.

Fermentation also allows many herbivores to recycle waste nitrogen, which is particularly important when low-protein diets, such as dry-season grasses, are consumed. Normally, the body gets all the nitrogen it needs from the breakdown of dietary proteins; when tissue proteins are de-

Erwin and Peggy Bauer

An immature common wombat cleans its fur. Like Australia's other two wombat species, it is equipped with long claws, ideal for digging its subterranean shelter.

Large tunnel systems, extending 100 feet or more, often shelter a number of wombats.

graded, the nitrogen released is quickly converted to urea, an unusable form of nitrogen that is usually excreted. When urea is released into the gut, however, microbes consume it and convert it back into useful nitrogen. In collaboration with John Nolan, a nutritionist at Australia's University of New England, Hume and I found that wombats were able to reuse 42 percent of the nitrogen from the urea. This extremely efficient recovery of waste nitrogen minimizes the amount of dietary protein the wombats need compared with kangaroos and sheep.

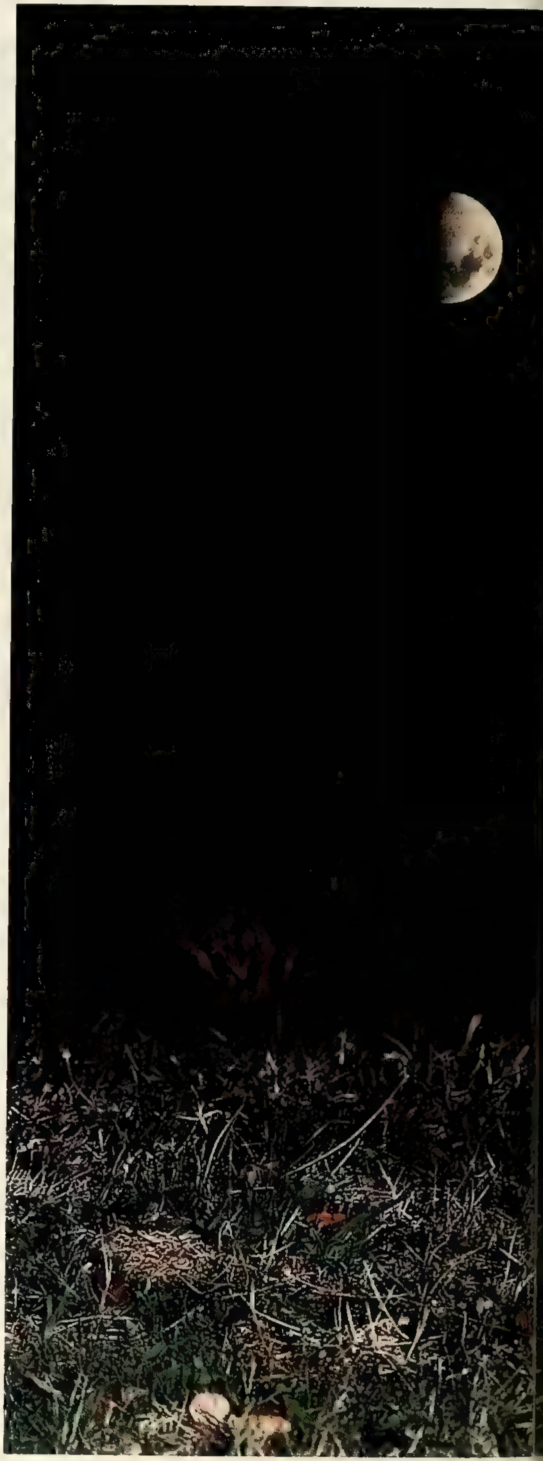
We also found that, relative to size, wombats' energy requirements are lower than those of other mammals; wombats use only 32 percent as much grass as grazing kangaroos and 25 percent as much as sheep. Extremely low levels of thyroid hormones indicate that wombats have a very slow metabolic rate. Important metabolic organs, such as the heart and liver, are also much smaller in wombats than in other animals of similar size.

The wombats' deep burrows help them conserve energy and water. Below ground, temperatures are less variable and milder than at the surface. And because wombats usually emerge at dusk or during the night, when air temperatures at the surface differ little from those of their burrows, the amount of energy they expend to maintain body temperature is minimized. The lower temperature and higher humidity of the burrows, combined with a slow metabolism, reduce the wombat's need for water. Working with Bronwyn McAllan and Julie Roberts, both kidney physiologists at the University of New England, I found that the kidneys of the hairy-nosed wombats can produce an extremely concentrated urine that rids the body of waste with little water loss—a particularly important adaptation in semiarid grasslands.

John Cancalosi; DRK Photo

Because wombats can subsist on very little compared with other grazers, they can minimize the time they spend foraging. When grass is scarce, they can also weather the shortage by feeding on the poorest quality foods, such as highly fibrous sedges. And in good times, when food is abundant, wombats can easily meet the extra energy requirements that growth and breeding entail since their basic requirements for body maintenance are already low.

In nature, diet is all-important and often



means the difference between a species' surviving or becoming extinct as its habitat changes. The wombat's meager food and water requirements explain its success. Populations of common wombats have thrived where pastures have been extended and improved to provide abundant, high-quality grass for livestock. Hairy-nosed wombats, however, have not benefited from the introduction of livestock because they inhabit semiarid regions where little grass grows. Nevertheless, they can tolerate poor pastures that result from overgrazing and drought, and are able to recover quickly if conditions improve. The ongoing research of Chris Johnson, a zoologist at James Cook University in Queensland, and others suggests that removing livestock from the range of the endangered northern hairy-nosed wombat has been an important factor in allowing the last, small population to rebound from about forty individuals to about sixty. Two populations of this species have disappeared within the last century, however, suggesting that there are limits to how much habitat change they can tolerate.

Nevertheless, their resilience to environmental change and human disturbance seems almost as robust as their sturdy physique—a comforting thought for this stocky scientist. ☐

A hairy-nosed wombat's burrow entrance, opposite page, leads to a tunnel system that may extend as much as six feet below the surface. Thriving in the wetter, temperate regions of southeastern Australia and Tasmania, a common wombat, below, emerges at night to graze.

Ford Kristo

Natural-born Mothers

by Sarah Blaffer Hrdy

Motherhood is not as straightforward a matter as just turning on the milk.

On the day that the eleventh-century Italian saint Peter Damian was born, his mother was ready to call it quits. According to the saint's biography, written by his associate John of Lodi, his mother was "worn out by childbearing" and further disheartened by the reproach of an adolescent son who took her to task for bringing into the world yet another mouth to feed and one more son to add to her already existing "throng of heirs." In despair, the mother refused to nurse. The fledgling saint was on the verge of starvation when a neighbor, the kindly concubine of a local priest, intervened, reminding her that even a savage beast, a tigress or a mother lion, would suckle her own young. Could a Christian woman do less?

Five hundred years later, Italian poet Luigi Tansillo echoed similar sentiments in response to the widespread use of wet nurses—the main alternative to maternal breast-feeding in the days before the baby bottle. In a poem entitled "La Balia" (The Nurse), Tansillo wrote, "What fury, hostile to our common kind, / First led from nature's path the female mind . . . [resulting in] a babe denied its mother's breast?" In the following centuries, tens of thousands of babies in Europe were deposited in foundling homes or shipped to middlemen who contracted for a lactating woman to suckle them. In urban centers like Paris, the majority of babies were suckled by strangers. This traffic in babies led to staggering rates of infant mortality.

Reaction against wet-nursing reached a peak during the Enlightenment. In 1793, the French National Convention decreed that only mothers who nursed their own children would be eligible for state aid. The writings of Jean Jacques Rousseau inspired many reformers (although the great philosopher sent his own five children to foundling homes). Almost always, reformers invoked "natural laws," encouraging mothers to follow their instinctive urges to nurture their babies. "Look to the animals for your example," French physician and moralist Jean Emmanuel Gilibert admonished his patients. "Even though the mothers have their stomachs torn open. . . . Even though their offspring have been the cause of all their woes, their first care makes them forget all they have suffered. . . . They forget themselves, little concerned with their own happiness. . . . Woman, like all animals, is under the sway of this instinct."

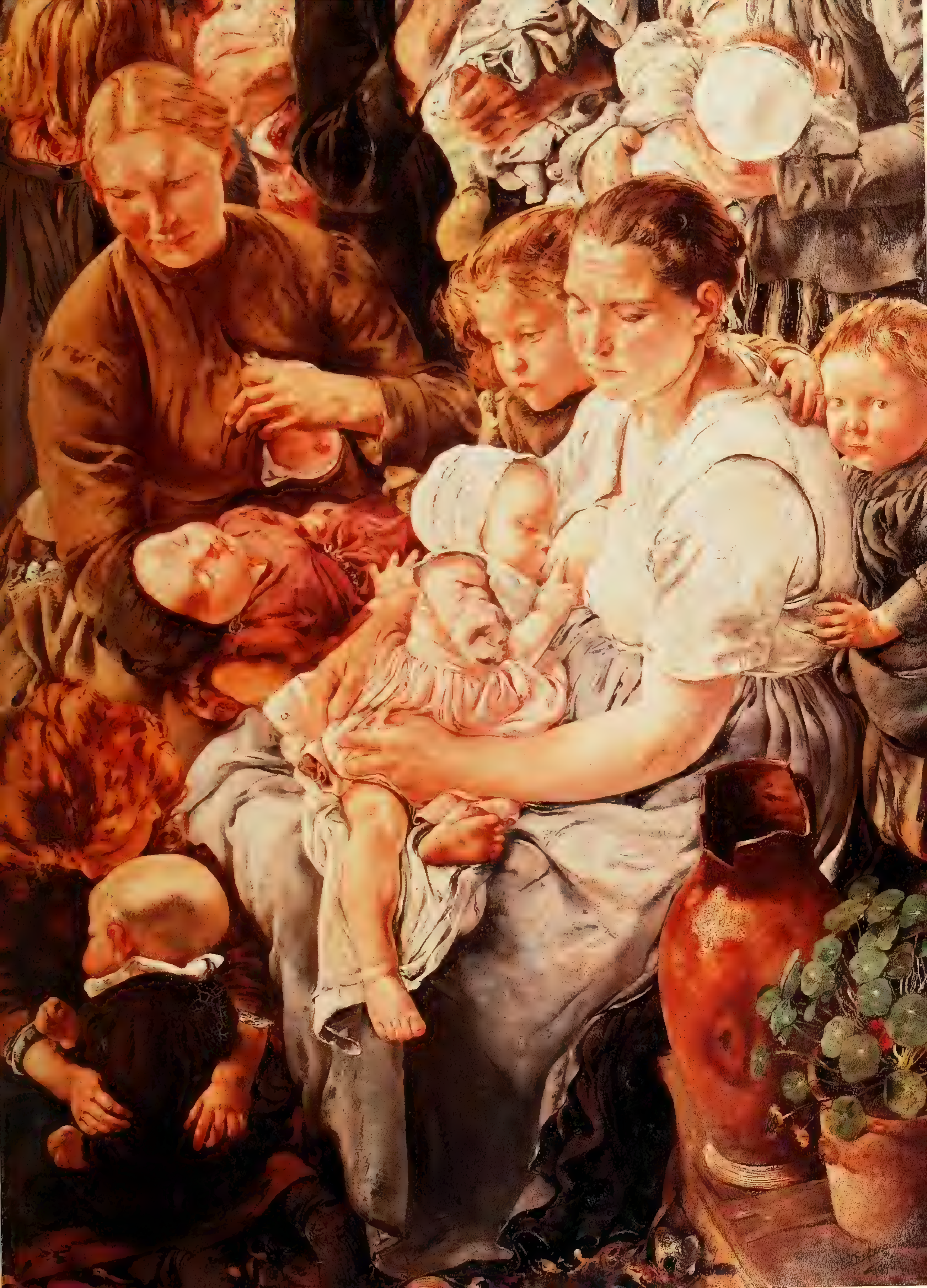
For further support of their beliefs, reformers could turn to Carolus Linnaeus, the father of modern taxonomy. A physician and the father of seven children, Linnaeus was an ardent advocate of maternal breast-feeding. In 1752 he set down his views in *Nutrix noverca* (Step-Nurse), a widely read denunciation of commercial wet-nursing (which Gilibert translated from Latin into French). In the 1758 edition of his opus *Systema Naturae,* Linnaeus subsumed all warm-blooded, hairy, viviparous vertebrates into a single group—the class Mammalia—identified with the milk-secreting glands of the female. (The Latin term for breasts, *mammae,* derives from the plaintive cry "mama," spontaneously uttered by young children from widely divergent linguistic groups and often conveying a single, urgent message, "suckle me.")

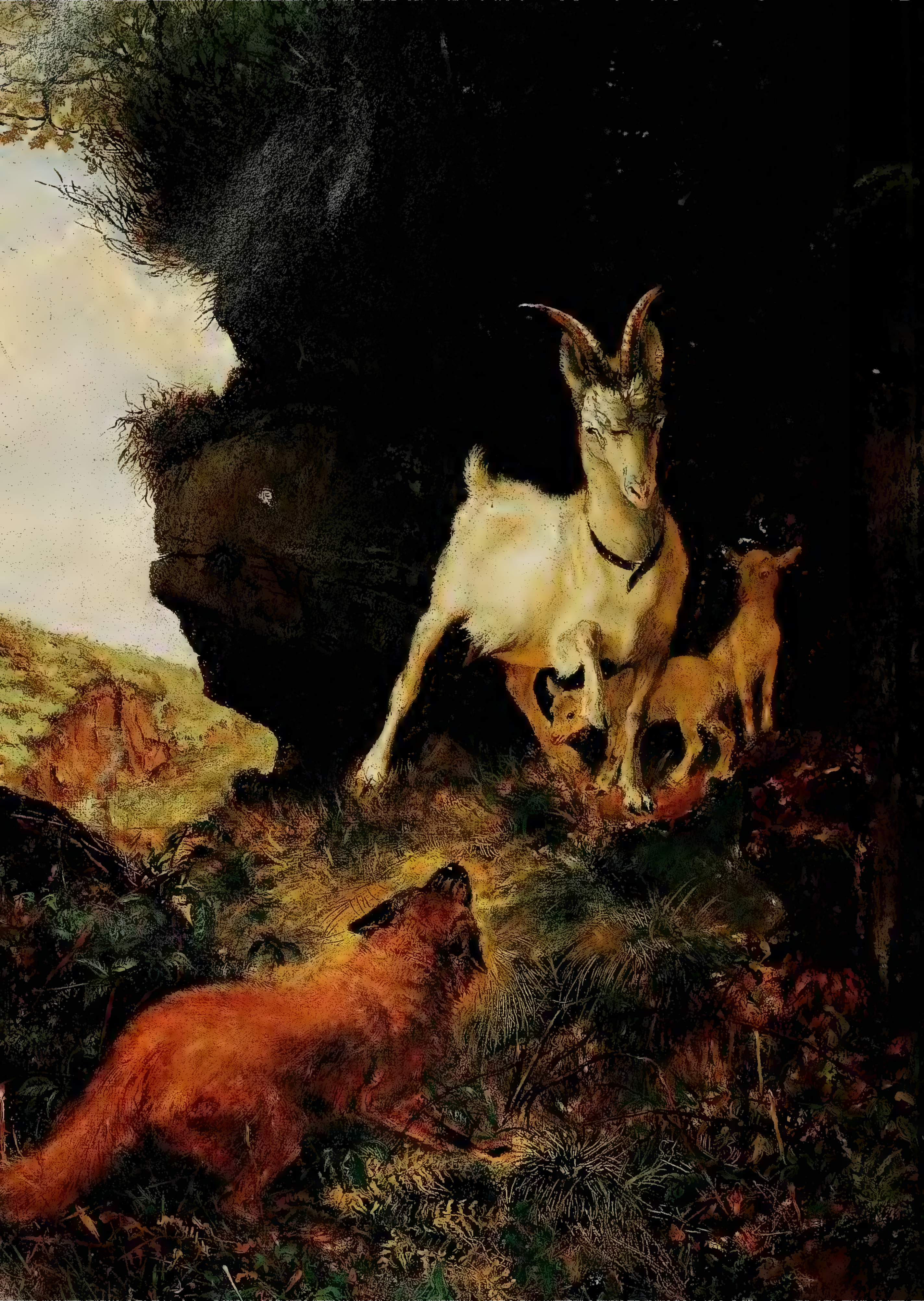
Linnaeus's nomenclature underscored a natural role for women based on a salient homology between women and other animals that nursed their young. Mother mammals are alchemists able to transform available fodder—grass, insects, even toxic leaves—into biological white gold. Lactation allows a mother to stockpile resources while they are available, repackage them in digestible form, and then parcel them out to growing infants at her own pace. Able to rely on its mother for food, an immature can stay safe either attached to the mother or stashed in hiding places she chooses, buffered from the vagaries and hazards of foraging in the wide world.

But motherhood is not as straightforward a matter as just turning on the milk. Mothers have to factor in recurring food shortages, predators, and social exploitation by members of their

This special section of Natural History *was prepared by senior editor Rebecca B. Finnell.*

The Age of the Worker—The Woman, by Léon-Henri-Marie Frédéric: Giraudon; Bridgeman Art Library





own species. Faced with poor conditions, a mother must weigh babies in hand against her own well-being, long-term survival, and—most important—the possibility of breeding again under better circumstances. Behavioral ecologists are only beginning to understand how mother mammals respond to such natural dilemmas, called fitness trade-offs.

Most mammals are iteroparous: breeding more than once, they produce offspring, either singly or in litters, over a breeding career that may last several years—twenty-five or more in the case of a woman. (A very few mammals—primarily some marsupial mice—are semelparous, breeding in one fecund burst followed by death.) In an evolutionary sense, the bottom line for iteroparous females is not the success of any particular birth but reproductive output over a lifetime. The art of iteroparity, therefore, is generally to survive poor conditions and breed again under better ones. By drawing on help from others, however, some mothers manage to breed under circumstances that would otherwise be impossible.

Consider the case of the cotton-top tamarins. Although the birth of twins is rare among primates, the pint-sized tamarins and marmosets of South America are exceptions. Adapted for fluctuating habitats, these monkeys have the potential to breed at a staggering pace, sometimes giving birth as often as twice a year to twins whose combined weight totals up to 20 percent of the mother's. Only the help of other group members—fathers, older offspring, and transient adults—makes the mother's feat of fecundity possible. Helpers carry the offspring most of the time, except when the mother is suckling. Near weaning, helpers also provide infants with crickets and other tidbits.

Working with captive cotton-tops, Lorna Johnson, of the New England Primate Center, revealed how important helpers can be. (This species is endangered in the wild but is still well represented in research colonies.) In her analysis of breeding records over an eighteen-year period, Johnson focused on experienced parents that had already successfully reared offspring. She found that among these veterans, fully 57 percent of parents without help abandoned their young, nearly five times the rate at which parents with helpers voted "no-go."

Among marmosets and tamarins, it is usual for only one female in the group to reproduce during a breeding season. A similar situation prevails among the communally breeding dwarf mongooses of the Serengeti. Studying what keeps the other females from breeding, Purdue University biologist Scott Creel discovered that estrogen levels of these nonbreeders remained only one-third as high as in the breeding female, below that necessary for ovulation. Creel speculates that in species producing large litters, heavy young, or young designed to grow rapidly after birth, the cost of gestation and lactation is just too high for any but the most advantaged female to hazard giving birth. Often harassed and less well fed, a subordinate has such a slim chance of producing young that survive to weaning that she is better off deferring

As bizarre as it may seem, when a mammal mother thwarts her own pregnancy, she is behaving—in strictly biological terms—just like a mother.

Still Life with Muskmelons, by Alexis Rockman. Collection of Lila Twigg-Smith; Courtesy: Jay Gorney, Museum of Modern Art reproduction, helping instead to rear the offspring of her kin—occasionally even suckling them—and generally doing her best to be tolerated in the group and to stay alive until she can become a breeder in her own right.

While studying a closely related subspecies of dwarf mongoose, O. Anne E. Rasa, of Bonn University, learned that subordinate females have an even more pressing reason to postpone reproduction. The dominant female may destroy the pups of any rival that does breed. Earlier this year, Duke University's Leslie Digby reported that there appears to be the same pattern among wild common marmosets in Brazil. In a rare instance when a subordinate female gave birth, one of her infants was killed; the other disappeared at about the same time. For marmosets and dwarf mongooses, then, most subordinate females make the best of a grim lot by temporarily shutting down their ovaries. With luck, their time to breed does come.

Suppression of ovulation is only one of the many means for mothers to adjust the timing of their reproductive effort. In a diverse array of mammals—including bats, skunks, minks, and armadillos—ovulation occurs, but implantation of the fertilized egg in the uterine wall is delayed so as to insure birth of the offspring at the

Hormonal Cocktails for Two

by Sarah Blaffer Hrdy and C. Sue Carter

When first presented with pups, a virgin female laboratory rat generally ignores them; she may appear afraid of the tiny, squirming, naked creatures and, occasionally, may even eat them. Only after being introduced to pups many times over several days can a virgin rat be conditioned to tolerate and care for them—licking them, crouching protectively over them, retrieving them when they stray from her side. In contrast, a pregnant rat responds within minutes to pups, even prior to delivery of her own.

The idea that physiological changes might prepare the expectant mother for her new role led to a now classic experiment. In 1968 Joseph Terkel and Jay Rosenblatt, of Rutgers University, injected blood from a rat that had just given birth into a virgin female. The result was a dramatic reduction in the time it took virgins to nurture pups.

Lioness with Her Cubs, by Giotto Di Bondone. Arena Chapel, Capella degli Scrovegni, Padua: SUPERSTOCK

Since 1968, we have learned a great deal about what goes on inside female mammals as they prepare for motherhood. During the last third of pregnancy, a cascade of endocrinological events readies and motivates mothers. Prominent in this maternal cocktail are the steroid hormones estrogen and progesterone, manufactured by the placenta and essential to maintaining pregnancy. But since the placenta is delivered along with the baby, progesterone and, a little later, estrogen levels fall around the time of birth. By themselves, these hormones cannot account for maternal responsiveness.

Enter prolactin and oxytocin, hormones essential for milk production and nursing. Prolactin is a very ancient molecule whose original function was to maintain salt and water balance in early vertebrates such as fish. Over evolutionary time, this hormone has proved very versatile and now performs diverse physiological functions in many kinds of animals. In mammals, it is associated with caretaking behavior in both females and males.

But perhaps the quintessential mammal hormone is oxytocin. A muscle contractor, oxytocin (from the Greek for "swift birth") evolved in mammals and produces the uterine contractions of birth and milk ejection during lactation. Present when the mother first greets her emerging offspring, it continues to be released whenever she nurses. Oxytocin released into the brain is known to promote calming and positive social behaviors, such as pair bonding.

Studies of domestic sheep by Barry Keverne, Keith Kendrick, and their colleagues at the University of Cambridge provide the most complete picture we have of the behavioral effects of oxytocin. As a lamb moves down the birth canal, nerves stimulated during the passage trigger the release of oxytocin in the mother's nervous system. Only if oxytocin is present at birth or injected so that it reaches the brain at the same time a mother meets her newborn, will she bond with her offspring. If release of oxytocin is blocked, the ewe rejects her lamb. High levels of oxytocin also are found in mother's milk, raising the possibility that this hormone plays a role in making the mother–infant attachment mutual.

As important as these hormones can be in determining how responsive a mother will be, they do not act in a deterministic fashion. They both affect and are affected by a mother's behavior and her experience. Exposure to pups, for instance, can lead to reorganization of neural pathways in a mother rat's brain, making her respond faster to pups in the future, even with lower hormone levels. And some recent studies suggest that the hormones of breast-feeding may benefit a mother's mental health and increase her ability to deal with stress.

In many mammals, males, as well as adoptive virgin females, can be primed to exhibit parental behaviors. Prairie vole males, for instance, typically respond to a newborn pup by retrieving it and huddling over it. Geert De Vries, of the University of Massachusetts, found that such nurturing is facilitated by vasopressin, a hormone that in other contexts is associated with aggressive, territorial behavior.

optimal season. As soon as a kangaroo mother ceases to suckle one joey, levels in her blood of the nursing hormone prolactin fall. At this signal, a tiny blastocyst (a nearly hollow globe of cells, produced by the fertilized egg, inside of which the embryo will develop) emerges from diapause (a period of developmental dormancy) and begins to grow again. In the European badger, this blastocyst-in-waiting continues to grow, but ever so slowly. Embryonic slowdown or diapause can persist for days in rodents or even months in larger mammals, until some cue signals the embryo to attach to the uterine wall and resume development. American black bears breed from May to July, but not until the female repairs to her den for winter does implantation occur, so that birth takes place to a lethargic mother in the snug safety of her winter refuge. Yet if the berry crop that year had failed, and the mother, as a result, was not in good condition, implantation might well have failed, too.

Planned parenthood primate style revolves around breast-feeding. In almost all monkeys and apes, as well as in people still living in traditional settings where infants enjoy nearly continuous contact with their mothers, babies nurse on demand. Emory University anthropologists Mel Konner and Carol Worthman report that the !Kung San of the Kalahari suckle their babies for two minutes or so as often as four times every hour, even while they sleep at night.

Throughout most of human evolution, mothers suckled their children on demand from infancy to the age of three or four—in some circumstances, even longer. A series of studies of hunter-gatherers from Central Africa, Botswana, and New Guinea, as well as of housewives in New England, have documented the dynamic interaction between a woman's nutritional status, her workload, and her fertility—what Harvard anthropologist Peter Ellison likes to call the ecology of the ovaries. Nipple stimulation from nearly continuous "Pleistocene style" suckling causes the pituitary to secrete more prolactin, the body's "work order" for more milk production. Through a complex and as yet poorly understood series of mediating effects involving the hypothalamus, ovulation is somehow inhibited when prolactin levels are high. The result is birth intervals as long as five years in long-suckling people like the !Kung. According to Ellison, the link between the intensity of suckling and postpartum infertility prevents a nursing mother, already energetically burdened by metabolizing for two, from

African Maternity Group Figure. Horniman Museum, London; photograph by Heini Schneebeli.

being saddled with another pregnancy and the even more daunting task of metabolizing for three. (Unless, that is, she happens to be particularly well fed. Worthman and others have recently discovered that among well-nourished mothers, the inhibition of ovulation by suckling is less effective.)

Like delayed implantation, lactational suppression of ovulation provides made-to-order birth control. No system is foolproof, however. Saddled with an inopportune conception, a mother mammal may resort to remedies that although unmotherly to modern tastes, are nonetheless utterly natural. Possible options depend on what type of mammal she is. Untimely fetuses may be reabsorbed, spontaneously aborted, abandoned after birth, or under some circumstances, killed and even eaten.

Milk: It Does a Baby Good

by Virginia Hayssen

A complex fluid with a long history, milk feeds us, protects us from disease, and even directs aspects of our behavior and physiology. The nutritional value of milk varies greatly from species to species. Cow's milk and human milk, for example, are both about 88 percent water and 4 percent fat, with 165 calories in an eight-ounce glass. Cow's milk, however, has 30 percent less sugar and three times more protein. For a low-fat milk, try that of black rhinos: their milk has only 0.2 percent fat. As a source of energy for their developing young, rhinos and horses use sugars instead of fats. The result is milk with only two-thirds the calories of human milk.

The cream of the crop is hooded seal milk, which is 61 percent fat, with about 1,400 calories in an eight-ounce glass. Small wonder the pups can gain forty-five pounds during their very short (four-day) nursing period. Hooded seals give birth on ice floes and must wean their pups before the ice breaks up or melts. The high-fat, low-protein milk is well suited to provide seal pups with the most important thing they need: a thick layer of blubber to insulate them against cold polar oceans.

The milk of chimpanzees living in tropical environments provides a striking contrast. There, where a mother may carry her suckling offspring with her everywhere for many months, mother's milk is very dilute, low in both fat and protein.

Mother hares, whose first priority is to provide a safe hideaway for their vulnerable babies and to keep its location a secret from predators, can only afford to let their young suckle once a day and, even then, for no more than five minutes. Not surprisingly, the milk of hares is rich in fat and protein.

Milk composition in many species changes over the course of lactation. Milk delivered in the early stages, and again as weaning approaches, often has more protein and less sugar than that produced during the interim stages. The kinds of fat in milk vary with the mother's diet. In fact, milk has different flavors depending on what mothers eat. Those flavors may later direct the food likes and dislikes of offspring.

Kangaroos are a special case in that mothers frequently suckle young of very different sizes and ages simultaneously. The youngest joey is attached to a tiny teat within the pouch and suckles constantly, while its older sibling, who may be 5,000 times larger, intermittently pokes its head into the pouch to suck on a much more elongated nipple. The milk from these adjacent teats is very different in composition.

The extent to which young mammals depend on milk for nutrition is also variable. Voles and mice rely completely upon milk for their well-being until weaning, while the young of many hoofed animals, such as deer and antelope, may begin eating grass only a few days after birth, well before weaning occurs. Mother koalas excrete a yellow-green ooze of partly digested eucalyptus leaves that their young energetically eat. The opening of the mother's pouch is directed backward, allowing the baby easy access to the nutritious slime.

In addition to nutrients, milk contains hormones and growth factors that can regulate the behavior and physiology of both mother and baby. As a mother nurses her young, subtle manipulations may be at work. Studies of rats, monkeys, and other animals have shown that nursing releases natural opiates in the mother's brain, perhaps rendering her more pliant to her baby's demands. Opiates are also present in milk, making the baby feel content, as well as well fed.

Lactation also acts as a fertility control. By suppressing ovulation, it tends to lengthen the interval between births, thus helping insure that each offspring (or litter) receives its mother's undivided attention. And experiments with rodents suggest that at least one component of milk delays puberty in female offspring by retarding ovarian development.

Another of milk's functions is immunological. Colostrum, the protein-rich fluid produced right after birth, is an important source of antibodies that confer immunity to various diseases. The protection provided by some other milk proteins, such as lysozyme and interleukin, may last throughout lactation.

The origins of milk and lactation will always remain somewhat mysterious. Without a time machine, reconstructing the early stages of any complex organ or process is difficult. As the English biologist St. George J. Mivart asked in 1871, "Is it conceivable that the young of any animal was ever saved from destruction by accidentally suckling a drop of scarcely nutritious fluid from an accidentally hypertrophied cutaneous gland of its mother?"

Nevertheless, we know that milk did evolve, and one of the proteins specific to milk—alpha-lactalbumin—may provide some clues as to how. Today, alpha-lactalbumin helps in the synthesis of lactose, but it evolved from another protein, lysozyme, common in blood and other body fluids, as well as in certain glandular secretions, including milk. Lysozyme kills bacteria and fungi, protecting animals from infection. It also protects milk from microbial attack.

Since lysozyme occurs in so many mammalian body fluids and milk, and since it gave rise to alpha-lactalbumin, this protein very likely was present in ancestral fluids that evolved into milk. The first mammals laid eggs, as the platypus and echidnas still do, and the early protomilk may have protected eggs or newly hatched young from bacterial or fungal attack. Because lysozyme is also a protein, neonates who lapped up the fluid from their mothers' bodies may have received a nutritional bonus. Eventually, the value of the fluid as a source of food and water became more important than its original, antibacterial function.

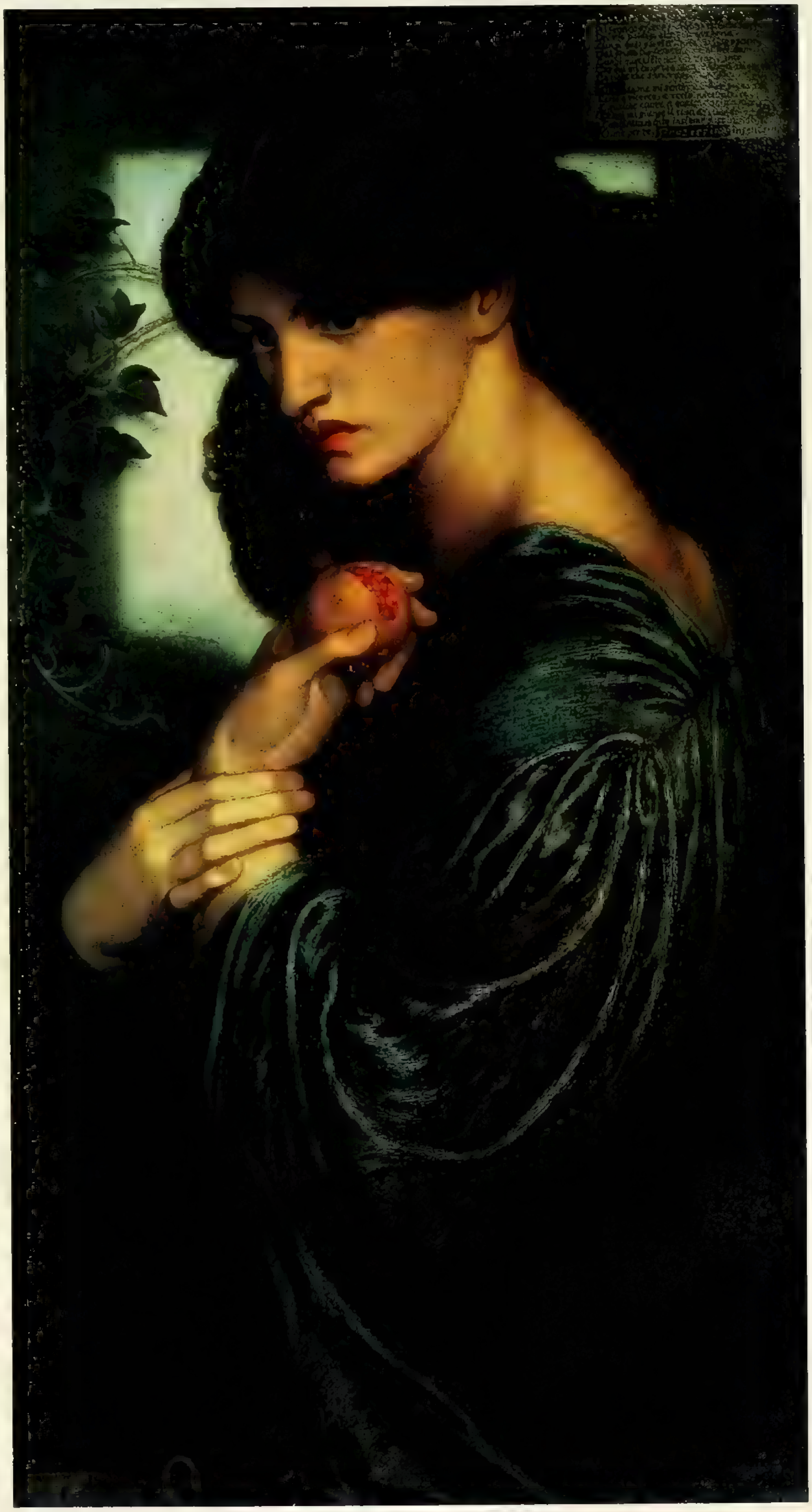
Golden hamsters, for instance, are highly flexible breeders adapted to the irregular rainfall and erratic food supplies in their native habitat in the arid regions of the Middle East. In addition to building a nest, licking their pups clean, protecting and suckling them—all pleasantly conventional maternal pursuits—these hamster moms may also recoup maternal resources otherwise lost in the production of pups by eating a few.

For hamsters, to quote Canadian psychologists Corinne Day and Bennett Galef, cannibalizing pups is an "organized part of normal maternal behavior which allows an individual female to adjust her litter size in accord with her capacity to rear young in the environmental conditions prevailing at the time of her parturition." Quality control can also be an issue. Among mice (but not hamsters), pups below median weight are the ones most likely to be rejected when mothers cull very large litters.

Another "rule of paw" might read: abort poor prospects sooner rather than later and, if possible, recoup resources. Recall how the mother bear's body factors in the latest update on food supplies before either canceling implantation or committing to gestation. The cues mothers respond to may derive from prevailing conditions or their own internal state. Biologist John Hoogland spent sixteen years monitoring a population of black-tailed prairie dogs in South Dakota. Mothers attempt to rear 91 percent of all litters produced; the rest of the time, they abandon their pups at birth and allow other group members to eat them, sometimes even joining in. Under closer examination, Hoogland found that the mothers that gave up on their litters weighed less. He speculated that abandonment was an adaptive response to poor body condition.

Deteriorating social conditions can also alter maternal commitment. Across a broad spectrum of animals from mice to lions, the appearance of strange males on the horizon can present a danger to unweaned infants sired by other, rival males. By killing these infants, the newcomers subvert the mother's control over the timing of her own reproduction. To minimize her loss, she breeds again sooner than she would have if she had continued to suckle her babies. Although this revised schedule of breeding is detrimental to the mother (not to mention her babies), she may ovulate again while the killer is still in the vicinity. Had the killer waited until her infants were weaned, his own window of opportunity might have long

Like their mammal cousins, human mothers have long played an active role in their own reproductive efforts. According to North Carolina State University historian John Riddle, the pomegranate was among the many plants used for birth control in antiquity. Riddle thinks this may explain the fruit's role in the Greek myth of Persephone, who was abducted by the god Hades to the underworld and doomed to stay there for part of every year. According to the myth, Hades fed her pomegranate seeds, which caused the months of fall and winter in the world above. Like these seasons, Persephone remained barren.



Persephone, by Dante Gabriel Rossetti. Tate Gallery, London; Art Resource

Working Women, 1987 ©1995 Marisol/licensed by VAGA, NY, NY; Courtesy: Sidney Janis Gallery, New York

The cues mothers respond to may derive from prevailing conditions or their own internal state.

since shut, for he too is bound to be replaced by another male.

Among the strains of house mice studied by Frederick vom Saal, at the University of Missouri, and by Robert Elwood, at Queen's University in Belfast, Northern Ireland, roving males that have failed to mate in the preceding seven weeks (equivalent to a three-week pregnancy, followed by four weeks of lactation) attack babies in any nest they bump into. By contrast, males that have mated during that crucial period are statistically more likely to behave "paternally," retrieving pups that have slipped out of the nest, keeping them warm, and licking them clean. Some behavioral switch accompanying ejaculation (especially if he remains near the female) transforms this potential killer into a kinder, gentler rodent. This transformation (Elwood calls it a "switch in time") saves the male from mistakenly destroying his own progeny (although, depending on circumstances, it may occasionally lead him to tolerate offspring of another male).

Male mice can also have a devastating effect on unborn young, for a pregnant mouse that encounters a strange male may reabsorb her budding embryos. This form of early abortion avoids the even greater misfortune of losing a full-term litter later on. It has become known as "the Bruce effect," after biologist Hilda Bruce, who first reported the phenomenon for laboratory mice in 1959 (at the time, its function was unclear). The Bruce effect has since been reported for deer mice, collared lemmings, and several species of voles. Elwood and others have shown that pregnant mice are especially likely to block pregnancies when confronted with males known to be infanticidal.

From the female's point of view, losing a pregnancy is scarcely an ideal strategy. Rather, her body is making the best of dismal circumstances. As bizarre as it may seem, when a mammal mother thwarts her pregnancy, she is behaving—in strictly biological terms—just like a mother. For she may soon conceive again, perhaps with a male who will stick around to help or at least keep other males away. Bruce had discovered a natural, spontaneous form of energy-conserving, early-stage abortion.

Mice are not the only animals that have to cope with infanticidal males. Among the lean and graceful langur monkeys that I studied at Mount Abu, Rajasthan, India, males pose serious threats to infants. My colleagues S. M. Mohnot and Volker Sommer, whose team has monitored the langur population at nearby Jodhpur for more than twenty years, learned that one-third of all infants born are killed by males coming into the group. Mothers initially avoid such usurpers or even fight back, but once a new male becomes ensconced in the group, he has the advantage of being able to try to kill the babies again and again, day after day.

Confronted with discouraging odds, a mother may try to deposit a nearly weaned infant with former resident males, now ousted and roving about the vicinity. This strategy rarely works. The infant will usually wend its way back to its mother, placing itself right back in harm's way. Especially if she is young with many fertile years ahead of her, a mother under persistent assault may simply stop defending her infant, leaving more intrepid kin—usually old females that have not reproduced for

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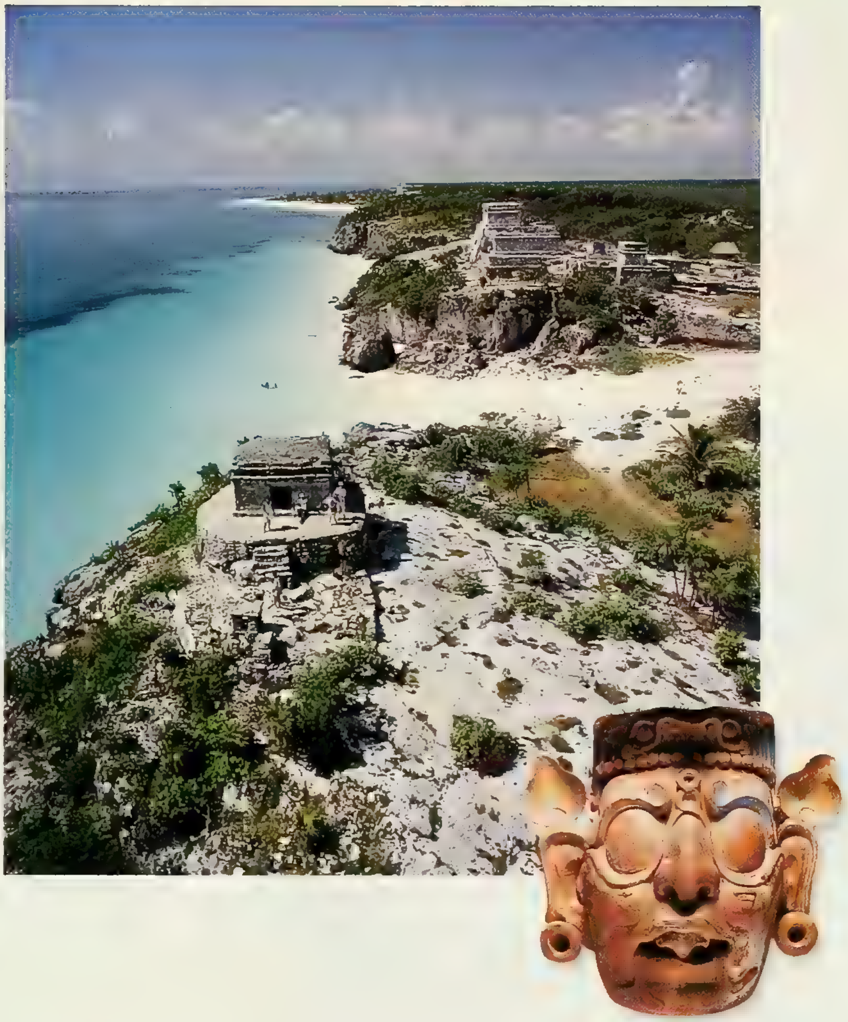

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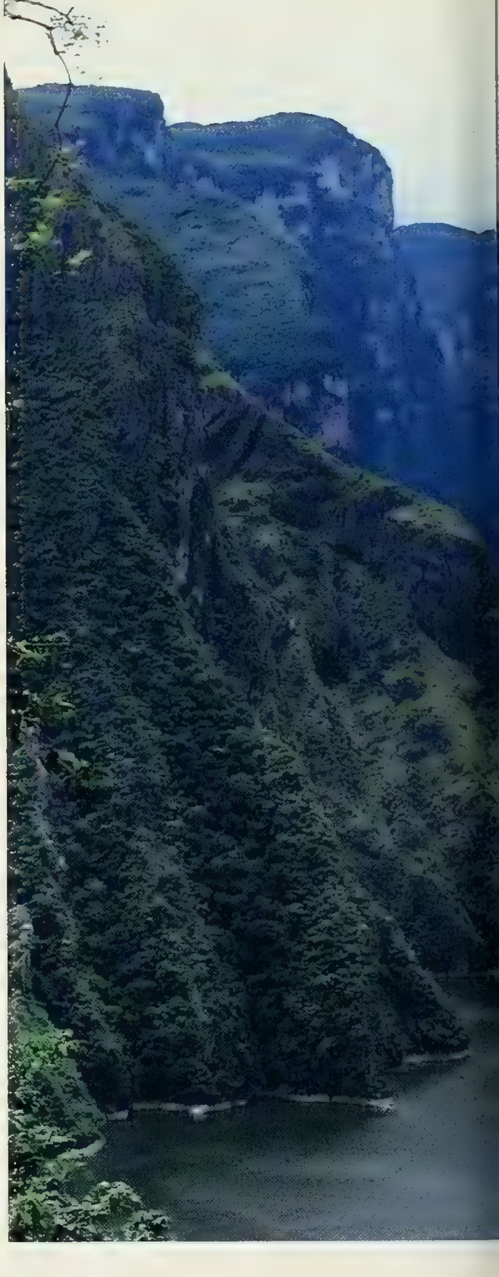
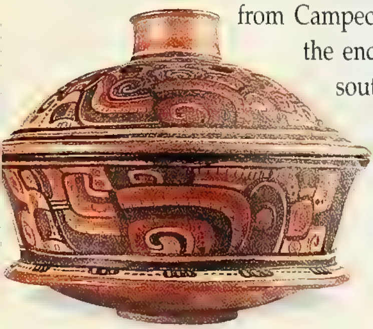


CAMPECHE *was the top port of call for rapacious 17th century pirates. Today, the modern state is an exciting destination for modern travelers with fortified colonial cities, built to fend off those greedy buccaneers, biosphere reserves and numerous Mayan ceremonial centers. The circuits described below are only suggestions and sites of interest can be visited in variety of different combinations.*

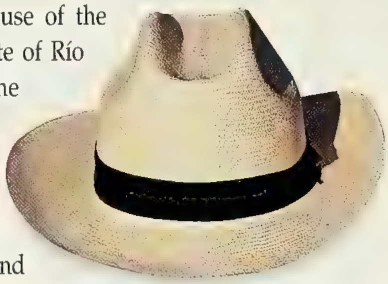
The state capital Campeche was once surrounded by a powerful two-meter-thick wall that incorporated forts and defensive fortifications. Now colonial churches and the remnants of walls, bastions and forts, often housing museums, showcase the state's turbulent and prosperous past.

South of Campeche, a two-day circuit takes the visitor to the fishing ports of Ciudad del Carmen and Champotón, with another colonial fort, on to the laid back beaches of Isla Aguada and a boat trip up the Candelaria river to observe the rich wildlife native to the region.

Travelers can visit the Mayan city of Edzná as a side trip from Campeche, or at the end of their southern circuit. It's the most important archaeological site in the state because of its impressive canal system, probably used for irrigation or drainage, and the imposing Temple of the Five Levels, which dominates the principal plaza.



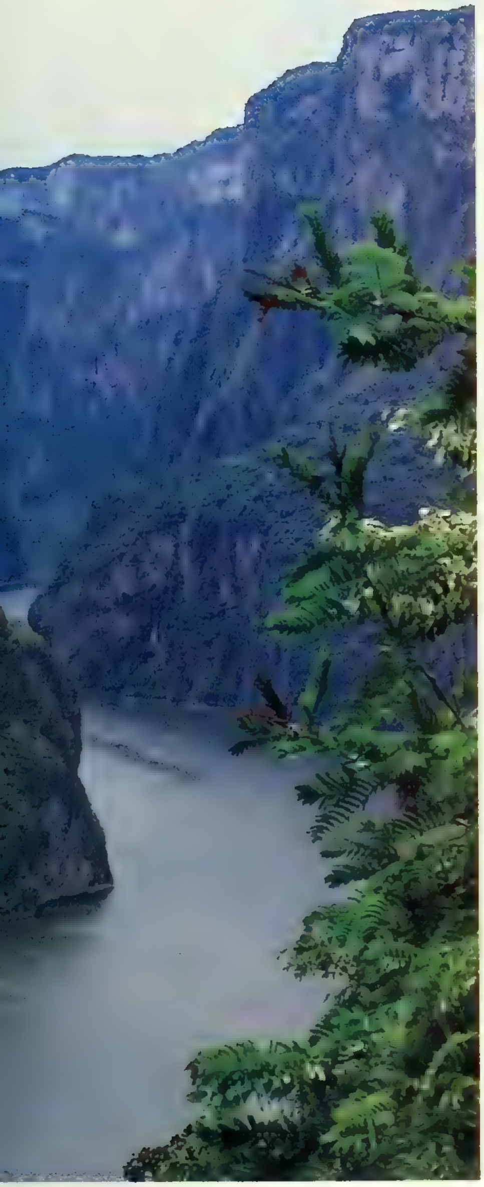
The Calakmul Biosphere Reserve and the Mayan settlements of Calakmul, Becán, Xpuhil and Chicanná can all be visited together. The reserve is one of the biggest in Mesoamerica and within its boundaries is a vast Mayan ceremonial center. Only a few kilometers separate Becán, Xpuhil and Chicanná, all built in the Río Bec style, characterized by long, low buildings, with huge serpents' mouths for doorways. In Mayan, Chicanná actually means "House of the Mouth of the Serpent." The site of Río Bec itself is deep within the reserve's jungles and difficult to reach.



FROM CAMPECHE: THE BASTION OF SAN MIGUEL (above left), A PANAMA HAT (above) AND A MAYAN BOWL FROM JAINA (left).

A north-bound circuit starting off from Campeche City begins at the Mayan burial ground of Jaina, a small island lying off the Gulf coast. Here the nobility were entombed with finely-modeled clay burial offerings. some of which are on display at the on-site museum.

Not far away are the handicraft centers of Hecelchakán and Becal, where connoisseurs claim the best Panama hats in the world are woven in damp caves to keep the palm fibers supple. Nearby Calkiní has an attractive colonial church.



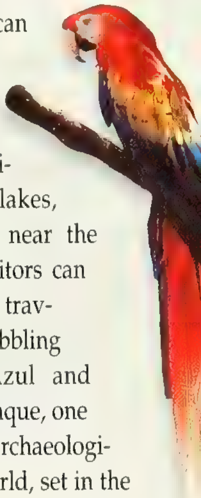
FROM CHIAPAS: A FESTIVAL AT SAN PEDRO CHENALHÓ (above right), SUMIDERO CANYON (above), A RED MACAW FROM THE STATE'S JUNGLES (right) AND THE JADE DEATH-MASK OF KING PACAL OF PALENQUE (below).

CHIAPAS *is a magical mixture of the modern-day Maya and a myriad of natural attractions. Living in the state's highlands, the Maya still follow ancient traditions and live much as they did centuries ago. Meeting them will transform a visit to Chiapas into an unforgettable experience. The circuits described below are only suggestions and sites of interest can be visited in variety of different combinations.*

The state capital of Tuxtla Gutiérrez has many fine hotels and restaurants. Visitors should stop by the magnificent Miguel Alvarez zoo, which only has animals found in Chiapas including the mighty jaguar. Nearby is the colonial town of Chiapa de Corzo, center of the Chiapan lacquer-making industry and jumping-off point for a boat trip down the daunting El Sumidero Canyon, rising more than 1,000 m above the Grijalva river.

Only two hours from Tuxtla is the mystical town of San Cristóbal de las Casas, a combination of Mayan culture from local villages and Spanish colonialism in both its domestic and church architecture. Visitors will enjoy a trip to the Mayan communities of San Juan Chamula, Zinacantán and Tenejapa to meet these ancient people and admire their fabulous weaving, examples of which are often for sale.

There's a wide range of accommodation and restaurants in San Cristóbal and travelers can use it as base to visit the town of Comitán and its museum of colonial art and the multicolored Montebello lakes, nestling in the forests near the Guatemalan border. Visitors can either return to Tuxtla or travel north-east to the bubbling waterfalls of Agua Azul and Misol Ha and onto Palenque, one of the most important archaeological sites in the Maya World, set in the depths of the emerald green jungle.



Structures like the Palace and Temple of the Sun are easy to explore and, inside the Temple of the Inscriptions, a royal tomb was found some years ago containing the skeleton of an ancient king wearing a splendid jade mask. From Palenque, it's easy to travel back to Tuxtla or to go to Villahermosa.

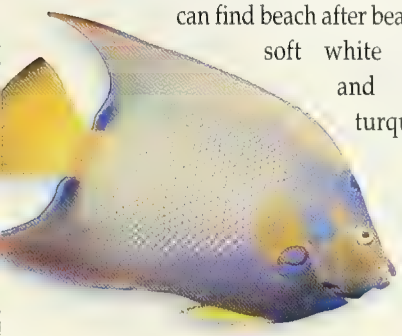
Deep in the dense rain forest are the ancient Mayan cities of Bonampak and Yaxchilán, which can be reached by small plane from San Cristóbal, Palenque or Comitan. Bonampak's chief glory is its murals, painted several thousand years ago but still fresh and brilliantly colored, showing the city at war with a neighbor. Situated beside the Usumacinta river, visitors to Yaxchilán can discover carved stelae and lintels adorning many of the buildings.

QUINTANA ROO *is one of the top destinations of the Maya World with the second-longest reef system in the world hugging its magnificent palm-lined coastline, majestic archaeological sites and modern megaresorts among its attractions. The circuits described below are only suggestions and sites of interest can be visited in variety of different combinations.*

With deluxe hotels, numerous restaurants and a wealth of shopping opportunities, Cancún is a modern vacation playground. Here visitors can begin exploring, whether their interests lie in ecology or archaeology.

Just 35 minutes by boat from Cancún is relaxed Isla Mujeres with the reefs of El Garrafon National Park lying off its shores while another short boat trip takes the visitor to the ecological sanctuary of Contoy. The island of Cozumel can be reached by a short 25-minute flight and, with its well developed tourist infrastructure and awe-inspiring reefs sheltering a variety of exotic fish, is a destination in its own right.

Cancún is the stepping off point for the Cancún-Tulum Corridor where visitors can find beach after beach of soft white sand and calm turquoise seas. There are numerous small towns to explore like Playa Del Carmen, Puerto Aventuras and Akumal, where it's possible to stay the night, and several other interesting destinations.



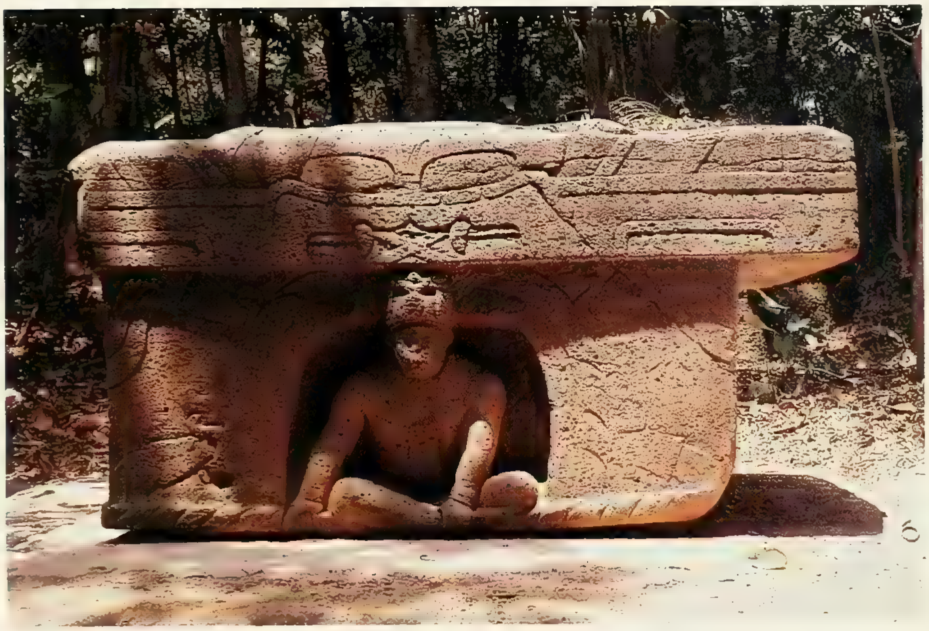
At the end of the corridor is the ancient walled Mayan city of Tulum, perched on a rocky cliff overlooking the Caribbean. Once the center of local trade, Tulum was one of the first places in the Maya World to be seen by Europeans during Juan de Grijalva's 1518 expedition. Only 30 minutes from Tulum is the city of Cobá where vast pyramids still slumber under heavy green vegetation.

Eco-tourists will want to visit the vast Sian Ka'an Biosphere Reserve, south of Tulum, which boasts an incredible variety of eco-systems and animal and bird species. Near Cobá is Punta Laguna, where a Mayan village is trying to protect a troop of spider monkeys and other native fauna and flora.

A day's drive away is the is the state capital, Chetumal. Set on the large Bay of Chetumal, wooden colonial architecture gives the city a strong Caribbean flavor. From here, visitors can explore the nearby seven-colored lagoon of Bacalar with the remains of the 17th century San Felipe fort and Cenote Azul, one of the deepest sinkholes in the world.

On the road to Campeche are the archaeological sites of Kohunlich with its vast two-meter high masks and the recently excavated city of Dzibanché, both worth a visit.

FROM QUINTANA ROO: A TWO-METER-HIGH MASK AT KOHUNLICH (above) AND AN ANGELFISH (left) FROM THE REEFS AROUND CANCÚN (above).



FROM TABASCO: THE GREAT ALTAR (above) AND AN OLMEC HEAD (right) FROM LA VENTA AND THE COLONIAL CHURCH AT CUPILCO (below).

TABASCO *is bisected by more than 1,000 miles of rivers bestowing a rich fertility on its soil. Juan de Grijalva landed here in 1518 and overpowered the local Maya, laying the foundation for the Spanish colonization of Mexico. The circuits described below are only suggestions and sites of interest can be visited in variety of different combinations.*

The affluent city of Villahermosa is filled with intriguing museums including the outdoor La Venta Museum Park, where huge Olmec heads weighing up to 20 tons line shady paths. The Olmecs preceded the Maya in Mesoamerica and were a vast influence on their culture. Following this visit, travelers can stop by the wildlife refuge of Yumká, just outside the city, which houses more than 400 species of flora and fauna.

An interesting two-day trip takes visitors south of Villahermosa to the 492-feet deep Coconá caves with their mysterious rock formations. Close-by is the important pre-Hispanic trading center of Teapa and the pretty colonial towns of Tapijulapa, with its red-tiled roofs and cobblestone streets, and Oxolotlán, which boasts a huge ruined convent high in the Tabascan hills. From here, it's not far to the Mayan city of Palenque in Chiapas.

Heading in the opposite direction, visitors can leave Villahermosa and spend a couple of days exploring the northern part of the state. Passing by cacao plantations, from which chocolate is made, visitors can explore the colonial town of Culipco with its extravangantly-painted church. Next is the unique Mayan site of Comalcalco where, thanks to a scarcity of local stone, the Maya devised bricks of clay, sand and ground shells to build their city. Comalcalco is near Tabasco's palm-starred Gulf beaches.

Adventure awaits at Agua Selva Reserve, an exciting project two hours from Villahermosa at the Sierra de las Flores, Huimanguillo. Meaning "jungle water," the name refers to the falls that are a highlight of the reserve, a legally protected zone marked for ecotourism. The Zoque people who live here are developing and promoting the reserve, with the help of government agencies.

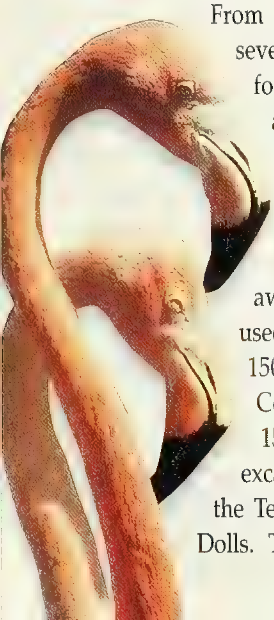
In the far-flung southeastern lands of Tabasco is the ancient Mayan city of Pomoná, built on the banks of the mighty Usumacinta river. With several fine carved bas-reliefs, Pomoná is historically and architecturally linked with the nearby cities of Yaxchilán, Chiapas, and Piedras Negras, just over the river in Guatemala. The town of Tenosique offers both hotels and restaurants for the weary traveler.

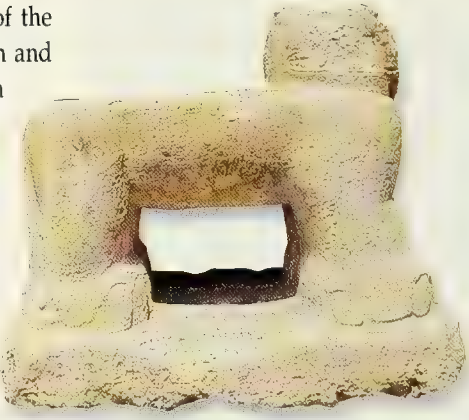
FROM YUCATÁN: UXMAL'S PYRAMID OF THE MAGICIAN (above), A CARVED STONE JAGUAR AT CHICHÉN ITZÁ (below) AND PINK FLAMINGOES (below left) FROM THE RÍO LAGARTOS RESERVE.

YUCATÁN *is a fascinating blend of colonial architecture and fabled Mayan archaeological sites. Offering haciendas, pyramids and huge colonies of pink flamingoes among its primary attractions, it's an exceptional travel destination. The circuits described below are only suggestions and sites of interest can be visited in a variety of different combinations.*

Founded in 1542, the state capital of Mérida is the oldest city in the peninsula and just one of its colonial gems is a cathedral built from the rubble of Mayan pyramids. Visitors can take horse-drawn buggies to the Paseo Montejo lined with mansions built with the profits of the henequen boom in the late 19th century. Try some of the delicious Yucatecan cuisine including *pollo pibil* (chicken cooked in banana leaves).

From Mérida there are several one-day trips, for example to the archaeological site and *cenote* (sinkhole) at Dzibilchaltún, only a few kilometers away. The site was used by the Maya from 1500 B.C. until the Conquest in the 1540s but the only excavated structure is the Temple of the Seven Dolls. Thousands of artifacts were discovered at the bottom of the cenote by a National Geographic team and visitors can refresh themselves with a swim in its depths. West of Mérida, visitors can enjoy a day in the Celestún National Park watching its flamingo and egret population.

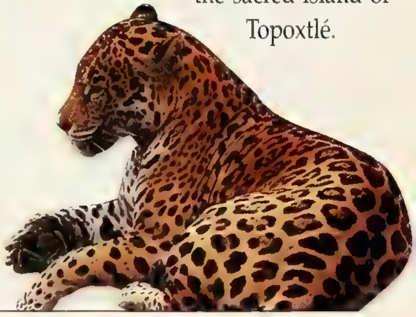




A two-day trip takes the visitor south along the Convent Route, linking many intriguing colonial convents and churches, to Loltún Caves with its impressive formations. Visitors can overnight near the Mayan city of Uxmal and the next day explore the site and neighboring Kabah, Sayil and Labná, all with delicate stone carvings and huge masks of the Mayan rain god Chaac. On the return journey to Mérida, don't miss the former henequen hacienda of Yaxcopoil.

Travelers can make a three- or four-day trip to the west of the state, visiting the bright yellow convent complex of Izamal on their way to the famous Mayan city of Chichén Itzá. Here the focal point is the mighty Kukulcán pyramid where, every equinox, the play of natural light on the north staircase creates the amazing illusion of a moving serpent descending the steps.

After an overnight stop, visitors can go bird-watching at the flamingo colony of Río Lagartos, travel to the attractive colonial town of Valladolid or visit the nearby Balancanché caves where archaeologists have found ancient offerings made to Chaac.



A MAYAN COUPLE IN TRADITIONAL DRESS (above) AND A JAGUAR.

GUATEMALA is full of villages with large Mayan populations and breathtaking scenery. From Guatemala City adventurers can hike to the top of Pacaya mountain near the city to see its frequent eruptions and lava streams. The capital is not far from the beautiful city of La Antigua Guatemala with its wealth of colonial architecture and traditions. To the west are the blue waters of Lake Atitlán, ringed by several Mayan communities and majestic volcanoes while a few kilometers north is Chichicastenango, home of a colorful Mayan market on Thursdays and Sundays.

In north Guatemala is Tikal National Park housing the immense Mayan ceremonial center of the same name. The city boasts towering temples protruding high above the lofty trees of the lush surrounding jungle, alive with the sounds of monkeys, parrots, jaguars and toucans. Other Mayan settlements near Tikal include Uaxactún, one of the oldest Mayan communities in the Maya World, and Yaxhá, beside the sacred island of Topoxtlé.

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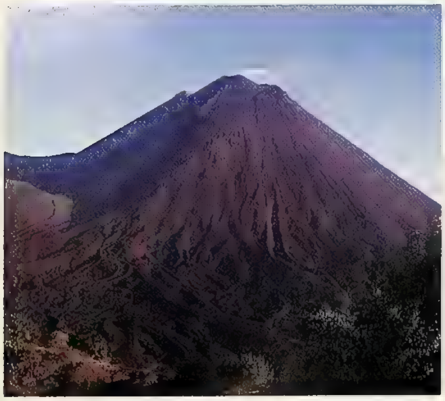

IZALCO VOLCANO IN CERRO VERDE PARK.

EL SALVADOR'S sites of interest include Joya de Cerén, known as "The Pompeii of the Americas" after a volcanic eruption more than 1,400 years ago covered this Mayan farming community under 20 feet of ash. Lake Coatepeque, the Montecristo Nature Reserve, Cerro Verde and several other nature reserves are home to howler monkeys, pumas, anteaters, toucans and a wealth of wildlife while other important Mayan sites in this central American country include Tazumal and San Andrés.

DIVING THE GREAT MAYA REEF.

BELIZE has several Mayan archeological sites, but this tiny Caribbean country is best known for the great diving and fishing off its many cayes. The fabulous reef lying along Belize's coast is rich in marine life while its rainforests, wetlands and mountains resound with the roar of the wild and its people are a colorful blend of Caribbean, European and Maya elements.

A CARVED STELA FROM COPÁN.

HONDURAS' capital of Tegucigalpa is within easy reach of the country's main destinations including La Tigra National Park, Lake Yojoa and the fabulous Mayan city of Copán, characterized by its intricately-carved standing sculptures. The Bay Islands in the Caribbean are a top destination for divers thanks to colorful coral formations making up the offshore reef system, home to numerous tropical fish.

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Guillermina Ibanez is eleven years old and is just starting sixth grade. She lives in **MERIDA** with her parents and two brothers. Hers is surely a warm, welcoming smile to Mexico.

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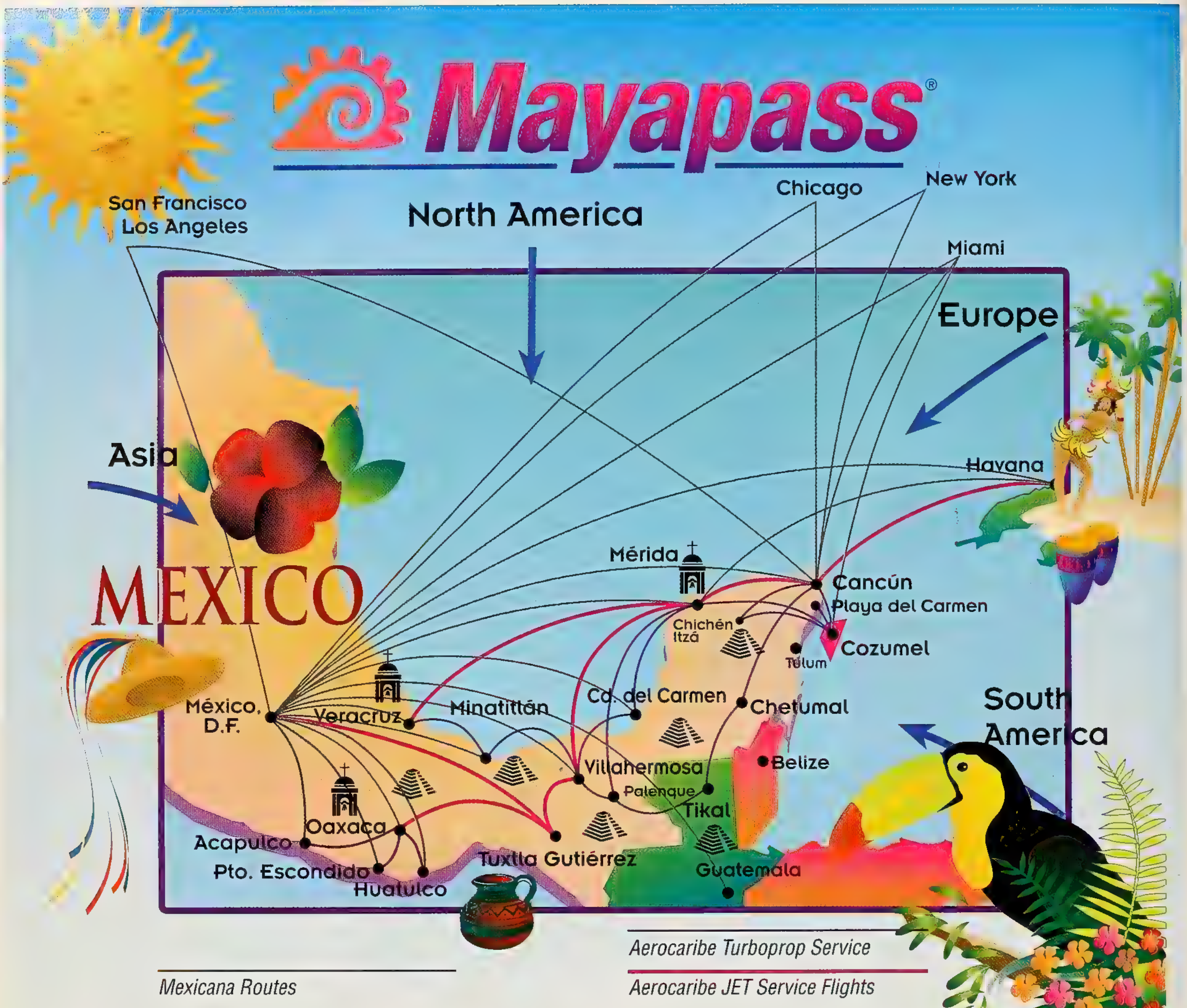
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Prenatal Power Plays

by David Haig

The most intimate human relationship is that between a mother and her unborn young. A fetus obtains all its nutrients and disposes of all of its wastes via its mother's blood. It shares every breath that its mother takes, every meal she eats, and draws on her fat reserves when food is scarce. What is the nature of this relationship? Do mother and fetus form one body and one flesh, a harmonious union with each attentive to the other's needs? Or is the fetus an alien intruder, a parasite that takes what it can without concern for its maternal host?

Neither the idyllic nor the parasitic vision adequately captures the complexities of pregnancy. Because they share half their genes, mother and fetus have common genetic interests, but sometimes their interests conflict because each also carries genes absent from the other. In particular, maternal and fetal genes are predicted to "disagree" over how a pregnant mother should allocate energy, time, and resources between her own needs and those of the fetus.

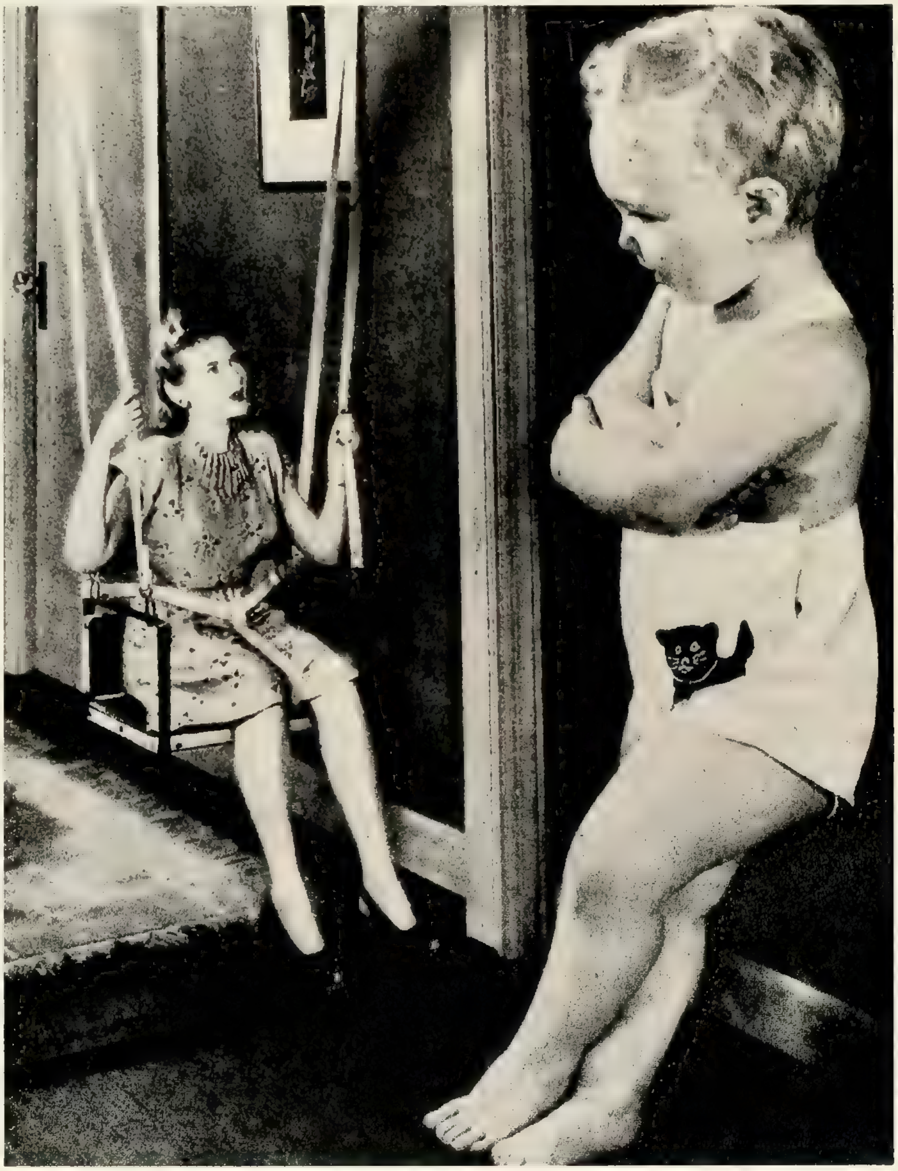
Mammal species vary markedly in the ability of the fetus to influence the amount of food it receives from its mother. Bush babies, for example, are small African primates with a placenta that simply absorbs uterine "milk" secreted by the glands of the mother's uterus. Other nutrients diffuse directly from the mother's blood to fetal blood across the thin layer of maternal and placental tissues that separates the two bloodstreams. A bush baby mother is probably able to control the flow of nutrients to her fetus by contracting or relaxing the blood vessels supplying the lining of her uterus. Similar arrangements occur in a variety of animals, including pigs, cows, and whales.

By contrast, the human placenta is invasive (as are the placentas of mice, bats, sloths, and armadillos). Uterine milk is a significant source of nutrients only during the earliest stages of pregnancy. As the embryo implants within the lining of the uterus, it sends out cells that invade the blood vessels supplying the uterine lining. These invasive cells destroy the muscular wall and greatly expand the diameter of the blood vessels. The result is that the fetus has direct access to its mother's blood, and the mother, unable to constrict the vessels, cannot regulate the flow of nutrients to the placenta without starving her own tissues.

Direct access to the mother's blood also enables the placenta to release a variety of hormones into her circulatory system. These hormones probably evolved to manipulate maternal physiology for fetal benefit. For example, human placental lactogen is produced in larger quantities than any other human hormone. One of its effects is to make maternal tissues less sensitive to the effects of insulin. If this effect went unopposed, maternal blood sugar would rise higher after meals and would remain elevated for a longer period, allowing the fetus to take a greater share of each meal. The mother is not completely powerless, however, and responds by increasing insulin production. Mothers usually maintain control of their blood sugar during pregnancy, but when they do not, gestational diabetes develops and is relieved only with the delivery of the baby and its placenta.

An appreciation of the genetic conflicts of pregnancy may help doctors understand other medical complications of pregnancy. Sometimes the placenta has inadequate access to maternal blood. One way for the placenta to compensate is to increase the flow of blood by increasing maternal blood pressure. When accompanied by excessive protein in the mother's urine, this high blood pressure can be a symptom of a life-threatening condition called preeclampsia.

Both mother and fetus, of course, share one overriding interest: the successful outcome to pregnancy. To reach that goal, the mother-child relationship appears from the very start to be marked by negotiation and compromise, although negotiations sometimes break down.



Advertisement, 1946, reprinted in *Representations of Motherhood*, by Bassin, Honey and Kaplin. Courtesy of Yale University Press

Liquid Assets: A Brief History of Wet-Nursing

by Sarah Blaffer Hrdy

A Sumerian lullaby from the third millennium B.C. provides the first written record of wet-nursing. As the wife of Shulgi, ruler of Ur, sings her son to sleep, she promises him first a wife and then a son—complete with wet nurse. "The nursemaid joyous of heart will suckle him." Some of these nurses were from privileged backgrounds, their status elevated by contact with tiny scions.

In ancient Egypt, wet nurses were recruited from the harems of senior officials and appeared on the guest lists for royal banquets. Less fortunate wet nurses were actually, or effectively, slaves, and not all lived under the supervision of the babies' parents. The substitution by nurses of one baby for another, the source of topsy-turvy merriment in Gilbert and Sullivan, was seen as serious enough in ancient Mesopotamia to be specifically proscribed in the code of Hammurabi (1700 B.C.).

By the second century A.D., wet-nursing in Europe was an organized commercial activity. In Rome, commerce in mother's milk took place in the vegetable market around particular columns called *lactaria,* where wet nurses for hire gathered. By medieval times, wet nurses—paid, indentured, or enslaved—could be found throughout Europe.

However, the "heyday of wet nursing" (as historian George Sussman refers to it) was eighteenth-century France. It had long been a practice among the elite for infants to be nursed in their own homes or in the nearby countryside by carefully chosen nurses producing plentiful milk. Such babies tended to survive as well as if nursed by their own mothers. A growing population of urban artisans and shopkeepers, along with a rapidly increasing foundling population of abandoned babies, expanded the demand for rural wet-nursing. For various reasons, demand for affordable wet nurses far outstripped their local availability.

Parents were forced to seek wet nurses farther afield. An itinerant entrepreneur known as a *meneur* would contract with rural women and then, shortly after an infant's birth, bring a prospective wet nurse to the parents' home to pick up her charge. The *meneur*—a cartload of babies in tow—would then lead the wet nurses and their new charges back to distant rural destinations. Instances of babies being lost along the way occasionally surface in police records for Lyon and Paris.

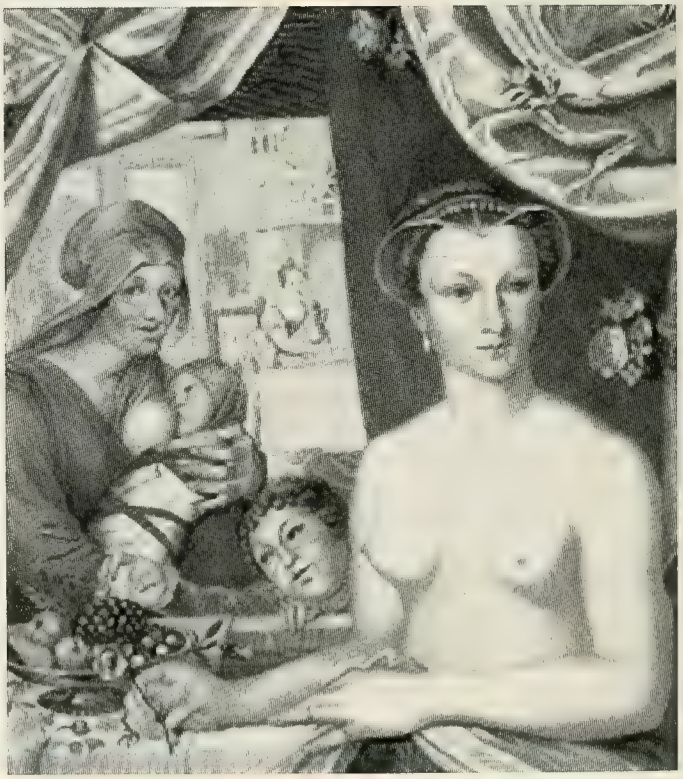
In 1780, Lt. Gen. Charles-Pierre LeNoir, head of the Paris police (whose job it was to monitor the referral bureaus used by parents to locate wet nurses) provided a startling statistic: only 1,000 of 21,000 babies born in Paris that year were nursed by their own mothers. Infant mortality rates during this period were appalling, and there was a direct relationship between how much parents paid a wet nurse and how likely her charge was to survive.

Whether the wet nurse was adequate or not, the consequences for the mother were the same. Freed from the "drudgery"—and contraceptive effects—of nursing, mothers ovulated again, often within months. During their prime reproductive years, some women gave birth annually, with such serious health consequences as chronic anemia and prolapsed uteruses. In privileged households, the beneficiaries were often the same husbands who had insisted on using a wet nurse in the first place. Without breaking prevailing norms against sex with a lactating wife, and at no physical cost to themselves, they produced an array of legal heirs.

Down the social scale, butchers and shopkeepers faced economic ruin without the help of their wives. Hiring a wet nurse was often a financial necessity. But even with a wife's help, couples could seldom afford—much less house—a choice nurse, so their infants were sent away, often to distant wet nurses. Many died. As in wealthier households, however, the production of babies was fast-paced: among the non-breast-feeding wives of butchers and silk makers in Lyon, French historian Maurice Garden documents one butcher's wife who had twenty-one children in twenty-four years.

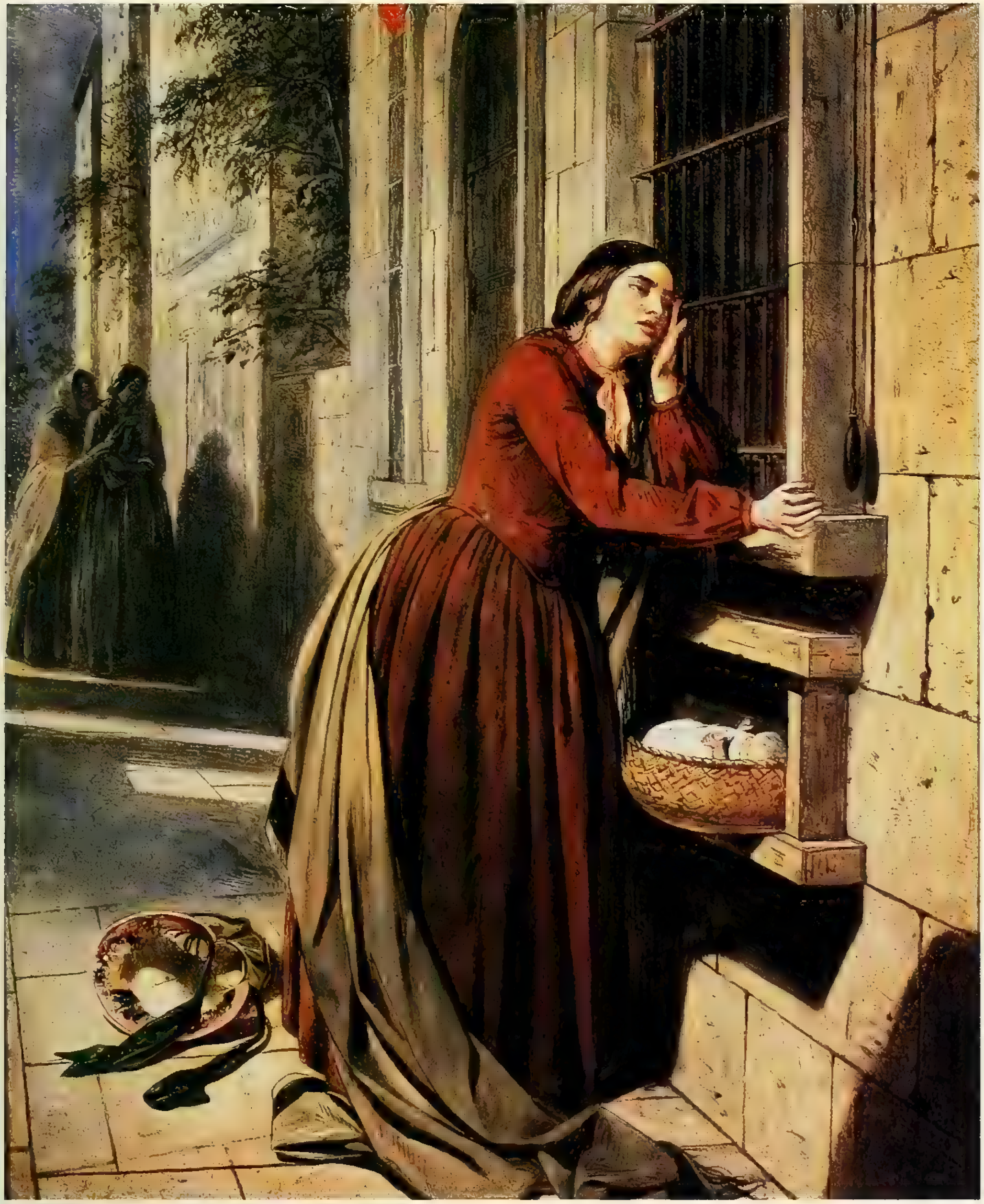
The real losers in the system, apart from the babies, were the women whose options were truly awful to begin with. Desperate to make any kind of living, many poor rural mothers would farm out their own babies to even less fortunate women and then hire themselves out as wet nurses. Grim reminders of their plight persist in how-to manuals for selecting wet nurses. Many recommend a woman who has recently given birth but who will not be nursing any infant other than the one she is hired to care for. (In a letter from Renaissance Italy, the wife of a Florentine merchant lamented the survival of a servant girl's baby; the enterprising lady had hoped to offer the servant as a wet nurse to one of her husband's clients.)

A few destitute women managed to work the system to their advantage, after a fashion. In Russia, where scores of abandoned babies were deposited in the (usually lethal) imperial foundling hospitals in Saint Petersburg and Moscow—established by Catherine II to demonstrate how "European" Russia was—an unmarried woman might become pregnant, abandon the newborn at the hospital, and then hire herself out as a wet nurse. Like the mother of Moses, a tiny, lucky percentage (if anyone in this tragic network would be considered lucky) managed to convince or bribe employees to put them in charge of their own infants.



Wet Nurse to the Child of Gabrielle d'Estrées, Mistress of Henri IV. Mary Evans Picture Library

Mother Depositing Her Child in the Foundling Hospital in Paris, ca. 1855–60, by Henry Nelson O'Neil. Coram Foundation, London; Bridgeman Art Library



In eighteenth-century France, many poor mothers would give up their own babies and hire themselves out as wet nurses.

years—to intervene. And so it was that I once observed an aged and stiff twenty-pound female, assisted by another older female, wrest a wounded infant from the sharp-toothed jaws of a forty-pound male. The far stronger and healthier young mother watched from the sidelines. Just days before, the same young mother had made no effort to intervene when her infant fell from a jacaranda tree branch and was grabbed up by the male. Again, it was the old female who rushed to the rescue.

In the last weeks of pregnancy, langurs may respond to a usurping male by aborting rather than continuing to expend energy on a reproductive venture so unlikely to end well. Similar late-pregnancy variations on the Bruce effect have been reported for an odd assortment of large mammals, including wild horses. University of Nevada's Joel Berger, an animal behaviorist who studied wild horses in the Great Basin, watched what happens when one stallion successfully challenges another for possession of his harem. During the disruption following the changeover, 82 percent of the mares that had been impregnated in the last six months by the deposed stallion aborted their fetuses.

Infanticide, abortion, cannibalism, these are altogether natural lapses from imagined "natural laws." Why is it only in the last two decades that researchers have begun to view such behaviors as other than aberrations? Opinions, even scientific ones, are often influenced by received wisdom. As late as the 1960s, when animal behaviorists set up labs to study the maternal activities of rats, monkeys, and dogs, the categories devised to describe their behavior took for granted that mothers were instinctively nurturing. In her pioneering studies of dogs, for example, comparative psychologist Harriet Rheingold separated mothers and their pups from all other animals and then recorded behaviors that fell into her preconceived protocol of maternal activities: contact, nursing, licking, play, and so forth.

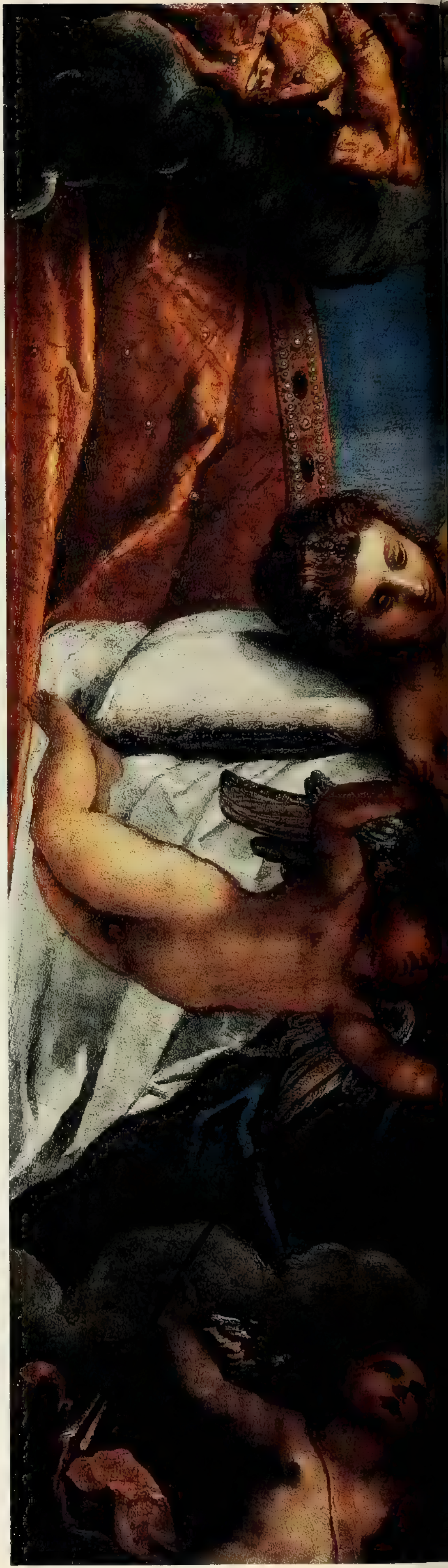
Indeed, much of the time mother mammals do carry, groom, and suckle their young. The types of maternal activities Rheingold and others investigated were those that insured that mothers passed on their genes to future generations—the primary focus of the time. Such a view of what it means to be a mother could fairly be classified as essentialist.

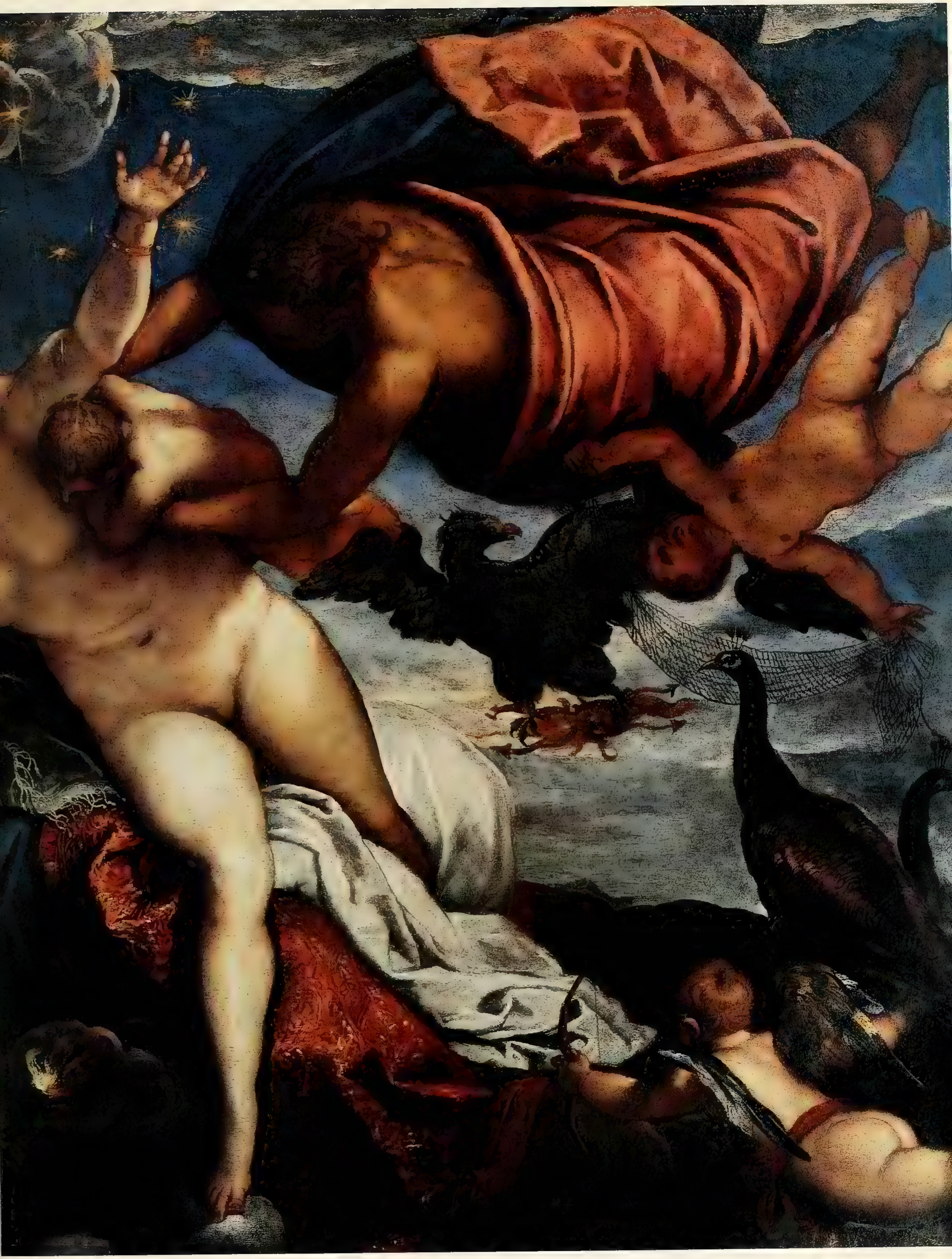
But the study of animal behavior has changed. With the emergence of sociobiology in the 1970s, researchers began to focus on individuals and the idiosyncratic social and environmental circumstances of each. With this new perspective, it not only became clear that one mother is not the same as another but also that not all females would be mothers. Far from essentialist or biologically determinist, most biologists today think context is critically important. Researchers like Scott Creel and Carol Worthman combine fieldwork with laboratory measures to search for the cues—inside and out—that prompt a female to opt for one reproductive strategy rather than another.

For most mammals, the art of reproduction is to survive poor conditions and breed again under better ones.

Across her life course, both a mother and her circumstances are constantly changing—as she ages, finds a new mate, loses a potential helper, stockpiles fat. In a world of leisure, plenty, and supportive social groups or in realms where offspring cost their parents little to rear, trade-offs fade from view. In contrast, overpopulation, social oppression, scarcity, bad times—none of these have ever been conducive to the development of the sort of mother characterized in Marge Piercy's poem "Magic mama" as "an aphid enrolled to sweeten the lives of others. The woman who puts down her work like knitting the moment you speak."

Real mamas must not only be magic but also multifaceted. Motherhood is more than all the licking, tending, suckling, and awe-inspiring protectiveness for which mother mammals are so justly famous. Such indeed is the art—and the tragedy—of iteroparity: offspring born at one time may be more costly to a mother or less viable than offspring born at another. Far from invalidating biological bases for maternal behavior, the extraordinary flexibility in what it means to be a mother should merely remind us that the physiological and motivational underpinnings of an archetypically prochoice mammal are scarcely new. ☐





The Origin of the Milky Way, by Jacopo Robusti, called Tintoretto. The National Gallery, London

Portraits of Prehistory

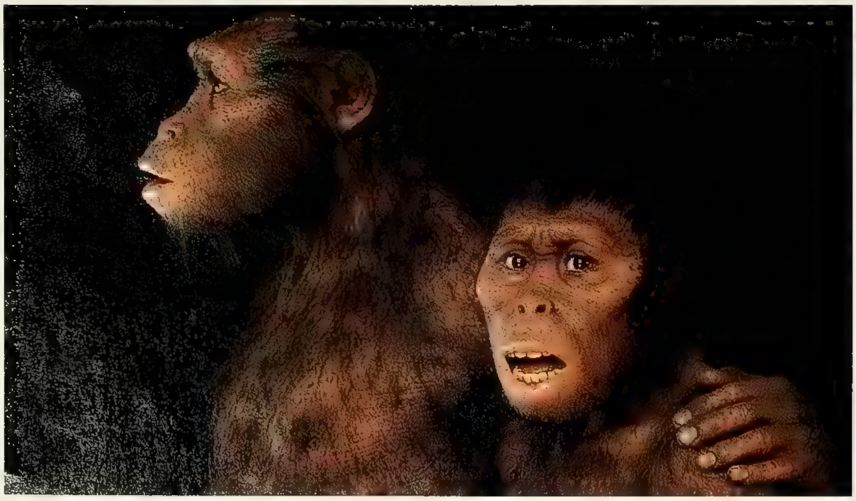
An English artist creates state-of-the-art sculptures of our remote ancestors

by Richard Milner

In Cornwall, southwest England, an unremarkable brick house of 1950s vintage sits on a quiet side road near the village of Sticker. In its cluttered garage, artist John Holmes pursues his special passion—sculpting images of humanity's remote ancestors. During the past few years, Holmes has become a full-time, one-man factory, producing re-creations of early hominids so lifelike they seem almost to breathe and blink. This past July, his sculptures of a male and female *Homo ergaster,* an early species of human that lived in East Africa some 1.7 million years ago, were installed in the American Museum of Natural History's Hall of Human Biology and Evolution.

Six years ago, physical anthropology curator Ian Tattersall and exhibit designer Willard Whitson were searching for an artist who could create realistic models of the four-foot-tall primates, known as australopithecines, that wandered East Africa long before *Homo ergaster*. Their quest took them to the Saint Louis, Missouri, zoo, where they were shown an exhibition model of Lucy, the three-million-year-old *Australopithecus afarensis* that was discovered in Ethiopia.

Tracing the sculpture to the exhibition department of the British Museum of Natural History, they were put in touch with Holmes. Tattersall and Whitson promptly hired him to create a pair of life-size australopithecines for the human biology hall.



Holmes's hominids: An australopithecine couple, above, are depicted crossing a volcanic plain in Africa 1.7 million years ago. One of their presumed descendants, a male Homo ergaster, *facing page, inhabited the same area some 2 million years later.*

Denis Finnin; AMNH

Now forty-three, John Holmes was born in Middlesex and grew up in the London suburbs. For most of his adult life he lived in London, yet he was always interested in natural history. As a boy, he recalls, "I was always picking up dead birds, searching for fossils, and pressing plants. But I was also extremely interested in art from an early age—the two combined, really." Although his school grades were only average, a teacher assured him that he could enter an art school on the strength of his drawings and sculptures. "But what I saw them teaching there didn't appeal to me—all this nonobjective stuff, welding bits of junk together. No one there, it seemed, knew how to paint a bird or a flower. So I skipped art school."

In 1969, Holmes began working at a commercial taxidermy company in Kentish Town, north London, mounting everything from antelopes to leopards. "I didn't really like the skinning out," he says, "but I did like the creation of the forms on which the skins were put—the sculpture side of it. It was an old company, and the senior workers were very Dickensian, using antiquated methods. Sort of like being in a time warp." After four years he left and considered himself lucky to find a place at the British Museum in its exhibition, design, and production department, which has since been disbanded. Hired as a model maker, Holmes remained at the museum for twenty years, crafting artificial plants, preparing dinosaur reconstructions, and working on dioramas and sculptures.

His work on ancient hominids began unexpectedly during the daily tea break at the British Museum. "We were all sitting around having our tea when there was a telephone call from America," he recalls. "It was a chap from the zoo in Saint Louis, wanting a restoration done of Lucy, the australopithecine. And the fellow who happened to pick up the phone just turned around and said, 'Is anyone here interested in doing this job?' At the time, I didn't have much going on, so I offered to do it on my own time, outside of the museum. And that's how it all started, really."

He had neither a roomy studio nor proper equipment. "When I lived in Tottenham, north London, I used to do all my work in a little converted bedroom upstairs in a terrace house. It was a terrible, tiny little place; there wasn't enough room to swing a cat." A few years later, he and his wife, Susan, moved to the countryside in Cornwall,

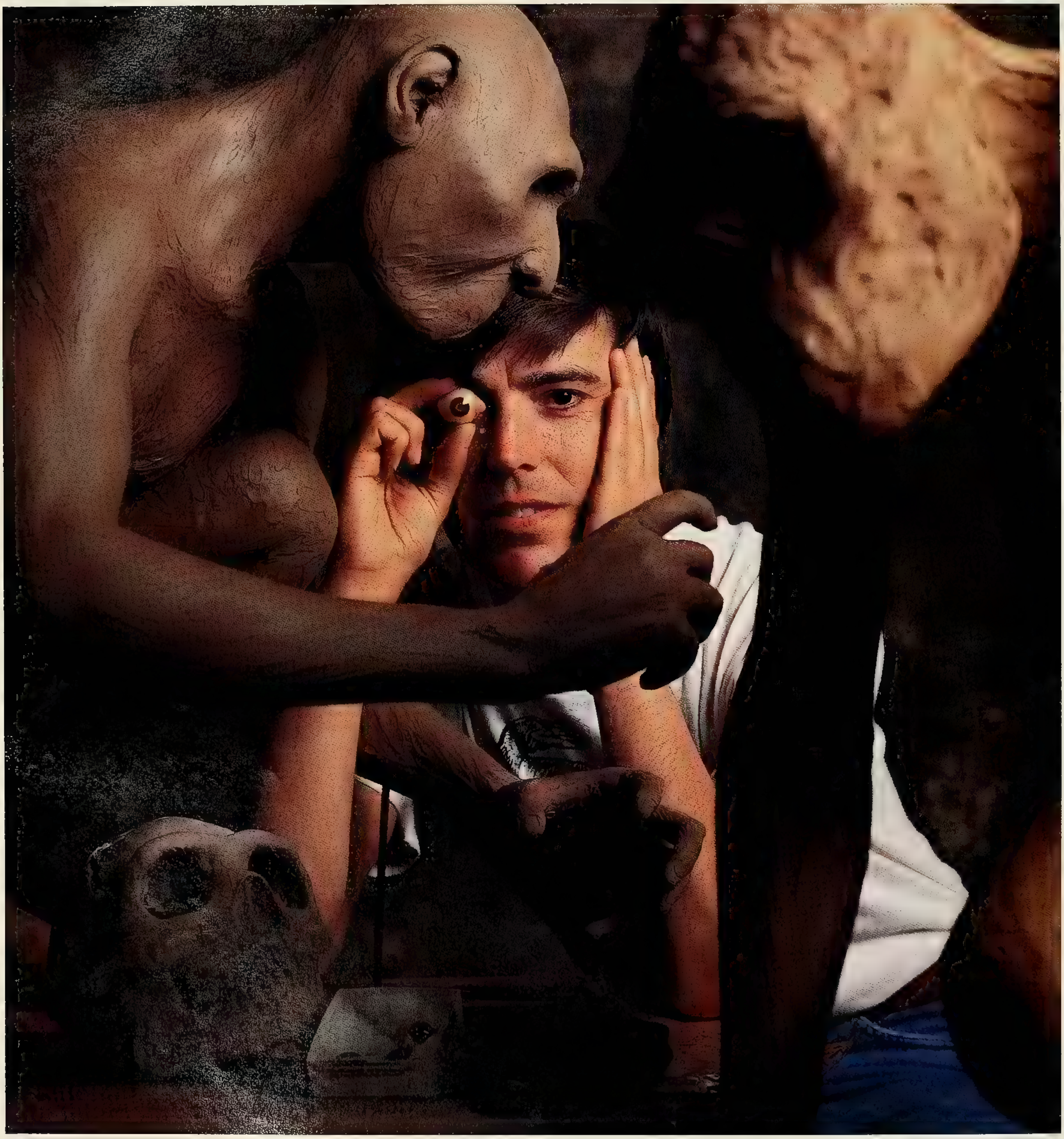
Denis Finnin; AMNH

Denis Finnin; AMNH

Denis Finnin; AMNH

Denis Finnin; AMNH

Tim O'Sullivan



Holmes's mastery of detail makes his figures seem almost to breathe and blink.

where hedgehogs, foxes, and hares are still plentiful in the fields and gardens. "I still have a very small, makeshift studio," he laments, "and I don't have anyone helping me. I'm like a one-man band, juggling all the different aspects of the work. Maybe I'm a little too much of a perfectionist. I didn't think the colors were quite right on ready-made glass eyes, so I create them myself out of resin and build up layers of translucent color for the details."

Holmes also disdains wigs, preferring to buy tiny plastic squares with three or four strands of human hair embedded in them. "You glue them onto the resin skin in rows, like putting tiles on a roof, working your way up to the crown of the head. It's very labor intensive." When he has finished adding every hair, wrinkle, and freckle, there is nothing generic about his creatures; one has a sense that they are specific individuals. "How he does it, I don't know for the life of me," Whitson enthuses. "There's something about the spark of the eye, the curl of the lip. He's like the great sculptor-taxidermist Carl Akeley, who created our Hall of African Mammals seventy years ago. Other mounted animals are accurate, but they don't have the animation that Akeley brought to his subjects, that sense of truthfulness."

"What Holmes did with the australopithecines," says Tattersall, "did not simply reflect that these were primitive hominids with striking similarities to apes in their skulls and heads; he brought them to life by making them look vulnerable, slightly worried. Here we have a couple of creatures, only four-feet-high, out there on the African savanna three and a half million years ago—a very dangerous environment. They have this rather apprehensive look on their faces, and they're looking in different directions; clearly, they're not happy out there in this almost vegetation-free environment. Very little cover, nowhere to go if they're ambushed by a leopard or other predator."

When Holmes began his work on the *H. ergaster* couple, Tattersall supplied him with photos, documentation, and casts of fossils believed to represent a male and female of the species. Holmes based the dimensions of his original clay models on these, transferring measurements with calipers from fossil cast to sculpture. "Each figure required more than twenty separate rubber molds before it could be cast in plastic resin. And I did the heads separately to make the casting process a bit easier."

When the sculptures were cast and assembled, Holmes then went over the bodies meticulously, adding color, surface texture, and finally hair. As with the australopithecines, the task took well over a year to complete.

"The vivacity of these early hominids is important in a museum where we have so many first-class animal dioramas with real specimens," says Tattersall, "but in this case, there are no actual hides, antlers, or hoofs to help the illusion. The trick is to make these fabricated creatures—built of fragmentary data, educated guesses, and imagination—look real. And in John Holmes we are fortunate to have found an artist who has that particular genius."

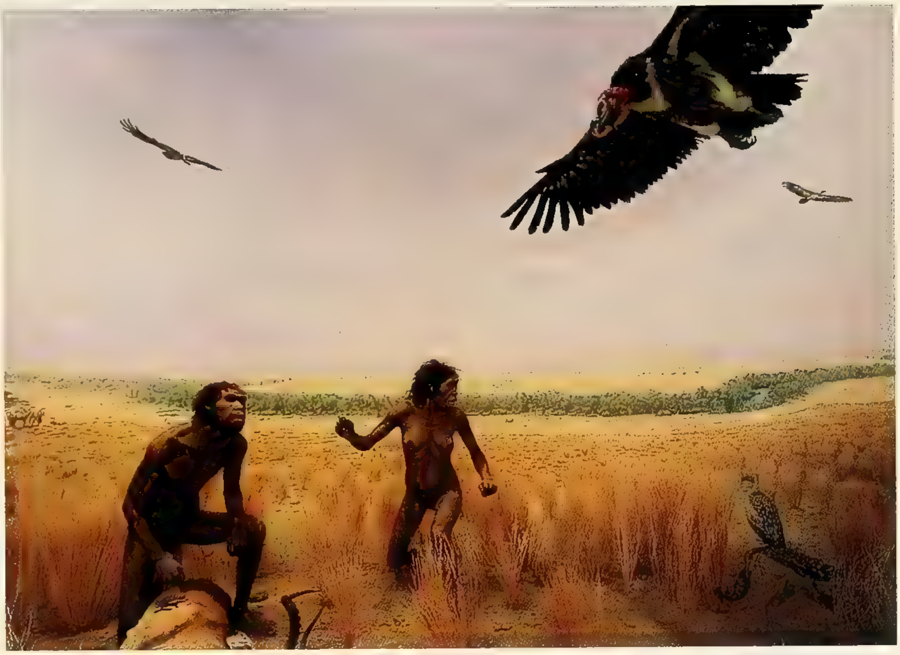
Richard Milner is a senior editor of this magazine.

At Home with *Homo ergaster*

In the new American Museum diorama, we see a male and female *Homo ergaster* trying to butcher an impala carcass while defending it from jackals and vultures. Whether early hominids were primarily hunters or scavengers of meat is still an open question. First identified in 1975 from a fossil jaw found in East Turkana, Kenya, *H. ergaster* (literally "work man") was given its name because of the stone tools believed to be associated with it. According to the Museum's curator of physical anthropology, Ian Tattersall, "these hominids were more comfortable with, and better adapted to, an open country kind of existence than the earlier, much smaller australopithecines. *H. ergaster* had larger bodies and had doubled their brain size. They stood taller and walked upright pretty much as we do today."

The new *H. ergaster* figures replace two earlier sculptures that were made before study of the "Turkana boy" skeleton (also on display in the Hall of Human Biology and Evolution) revealed the true bodily proportions of this species. In 1984, anthropologist Richard Leakey's team of fossil collectors from the Kenya National Museum discovered the amazingly complete skull and skeleton of a youth who died about 1.6 million years ago. Found near the western shore of Lake Turkana, the Turkana boy had been initially assigned to *H. erectus*, the same species as the classic Java man discovered a century ago in Indonesia.

"However," says Tattersall, "these Turkana, or *ergaster*, folk are different and don't belong in the same species as the Asian fossils. They seem to have been significantly less specialized, particularly in their cranial anatomy. The Turkana boy was slenderly built, with elongated limbs—like the people who live in that part of Africa today. They live out in the open under the tropic sun and would have a big problem with overheating, but their linear build maximizes the body's area available to lose heat."—*R. M.*



The new Homo ergaster *diorama in the Museum's Hall of Human Biology and Evolution*

J. Beckett; Denis Finnin; AMNH

Getting Your Goat

Old-time cowboys relished it—now there's a bull market for cabrito

by Robb Walsh

Goats are a touchy subject among cowboys. Calling a cowboy a "goat roper" not only implies that he lacks basic job skills but is also an easy way to get punched in the nose. Goats get no respect. You never see them in Westerns, despite the leading role they played in the real history of the Old West. The first cowboys on the open ranges of south Texas and northern Mexico ate goat more often than any other meat. While cowboy movie clichés like hitching posts and cattle drives are scarce in Texas these days, the goats are here to stay.

Columbus introduced goats to the New World on his second voyage in 1493. At the time, goat was the most common meat of the poor in Mediterranean Europe and much of the rest of the world. The English word "butcher" comes from the French word *bouchier,* which means "one who kills male goats." Goats were introduced into Texas and northern Mexico in the 1600s, and have thrived in the Southwest ever since with little or no attention from human beings.

Over the last hundred years, as beef, pork, and poultry became more affordable in North America, the consumption of goat meat declined. Until recently, Texas produced enough goat meat for the entire United States, with plenty left over to export to Mexico. Then, about five years ago, the goat meat market went loco; since 1991 sales have increased dramatically. This year, more than 150,000 of the animals will have to be imported to satisfy nationwide demand.

Surprisingly, the New York metropolitan area is now the center of goat consumption in the United States. There, new immigrants from the Caribbean, Africa, and Middle Eastern countries are buying nearly two-thirds of all domestic and 15 percent of imported goat meat. Once upon a time, people ate goat because it was cheap; today goat meat sells for up to five times the price of hamburger. Suddenly, there's a bull market for goats. And to Texas cattle ranchers, pinched by high costs and low beef prices, raising goats is starting to look like easy money.

The new interest in goats hasn't hurt the fortunes of Robert Kensing, the vice president of the American Meat Goat Association. I visited Kensing at his Bowie Springs Ranch, in Menard, Texas, where he and his wife, Doris, have been breeding Spanish goats since 1973. Today, goat ranchers from all over the country are coming to Kensing's ranch to buy their breeding stock.

"I had this vision of a bigger, better goat," he says as we admire his herd. "When I was a kid, um, I mean a child, the mature Spanish goats on our family ranch weighed about 80 pounds. We've done selective breeding for twenty-two generations. Now the mature goats on this ranch weigh up to 140 pounds."

We wander back to the shade of the porch where Doris Kensing invites me to stay for dinner. "It's just beef stew," she apologizes.

"Sorry, we don't often eat our own goats," Robert Kensing explains. "They're too valuable." Kensing's goats are sold exclusively as breeders and command as much as $500 a head.

Although the menu doesn't feature goat, the conversation does. Even when goat meat was cheap, goats were valuable to ranchers on the scrubby Texas range. According to range ecologists, a managed herd of goats will actually improve the quality of the rangeland they graze by eliminating brush and weeds that other livestock can't digest. The Mexican cowboys passed on the old Spanish shepherds' traditions of goat eating, Kensing says. But according to him, the real reason goat meat became a tradition in the Old West was the small size of the carcass. A few cowboys out on the open range couldn't eat a whole cow, but a fifteen-pound kid was just the right amount for dinner.

"Before refrigeration, you couldn't kill a cow out on a little Texas Hill Country ranch either. There was no way to store the meat," Kensing explains. "When I was growing up fifty years ago, we ate a lot of goat." Mexican ranch hands cooked *cabrito* (baby goat) on an open fire, he remembers, while his mom just baked it in the oven. He and his wife agree: there is nothing in the world that can compare with the flavor of crispy goat ribs.

The beef stew is delicious and I go for thirds on Doris Kensing's fresh green beans. But all this talk of crunchy goat ribs and cowboys cooking on open fires has gotten to me. As I drive away, I am dreaming of goat.

It's ironic that what was once the most common meat in these parts has become hard to find. You don't often see goat meat in neat little plastic packages in the supermarket. If you want to cook some, you generally have to buy a whole goat, which I once did for a family barbecue. Unfortunately, I had no idea what I was doing and made an awful mess of it. Now I'm wondering if there's anywhere I could get the recipe for old-fashioned cowboy *cabrito.* I ask in a couple of restaurants that serve stewed *cabrito* in Austin and San Antonio. They tell me that if you want to learn how to cook goat the way the old-time cowboys did, you have to go to Mexico.

Interstate 35, which runs through my hometown of Austin to the border at Laredo, follows the path of the old Chisholm Trail. South of San Antonio, I pull off at a rest stop and take a look around. In between the mesquite thickets, the flat, golden grasslands fade off in all directions as far as the eye can see. There aren't many goats or sheep out here anymore.

But in the eighteenth century, this land was home to tens of thousands of sheep, goats, and cows. In the days before fences, the *pastores,* or shepherds, stayed with their flocks and kept the predators at bay. As the herds and distances increased, they began to do their work on horseback. The mounted shepherds were known as *vaqueros,* the word we translated to buckaroos or cowboys.

The switch from walking to riding required changes in the clothing and tools of the shepherd's trade. Pedestrian footwear was replaced by boots designed to fit into stirrups. Large-brimmed hats to ward off the sun became *de rigeur*. Nowadays, you'll still see the cowboy boots and cowboy hats the *vaqueros* invented on West Texas ranchers who ride herd in helicopters.

There's a big difference between the quiet streets of Laredo and the riotous squalor of Nuevo Laredo just across the border. But beyond the city, I reenter the same scrubby rangeland I left on the other side. Driving down the road at dusk, passing women leading donkeys, I see tiny plumes of smoke rising here and there in the enormous open spaces between the mountains. If I want to taste authentic cowboy goat, I figure I should just park my car on the shoulder and hike toward one of those campfires.

I try to think of what I would say after a five-mile trek through the desert. "*Cabrito*, my favorite! Hope I'm not intruding." Unfortunately, I can't remember the Spanish word for "intruding," so I decide I'd better push on to Monterrey.

Young Spanish goats are penned awaiting sale at the Junction, Texas, livestock auction.

Robb Walsh

It's not much of a challenge to get a Monterrey resident to talk *cabrito* with you. It's like getting a New Yorker started on pizza or listening to a San Franciscan rant about sourdough—a civic obsession. After consulting with a few bartenders and taxi drivers, I find my cowboy *cabrito* at El Tio's Restaurant on Hidalgo Street. In response to my barrage of questions, the waiter escorts me to the open-air kitchen for a demonstration. In the middle of the brick courtyard in the outdoor dining room, a circular brick pit holds a simple open fire.

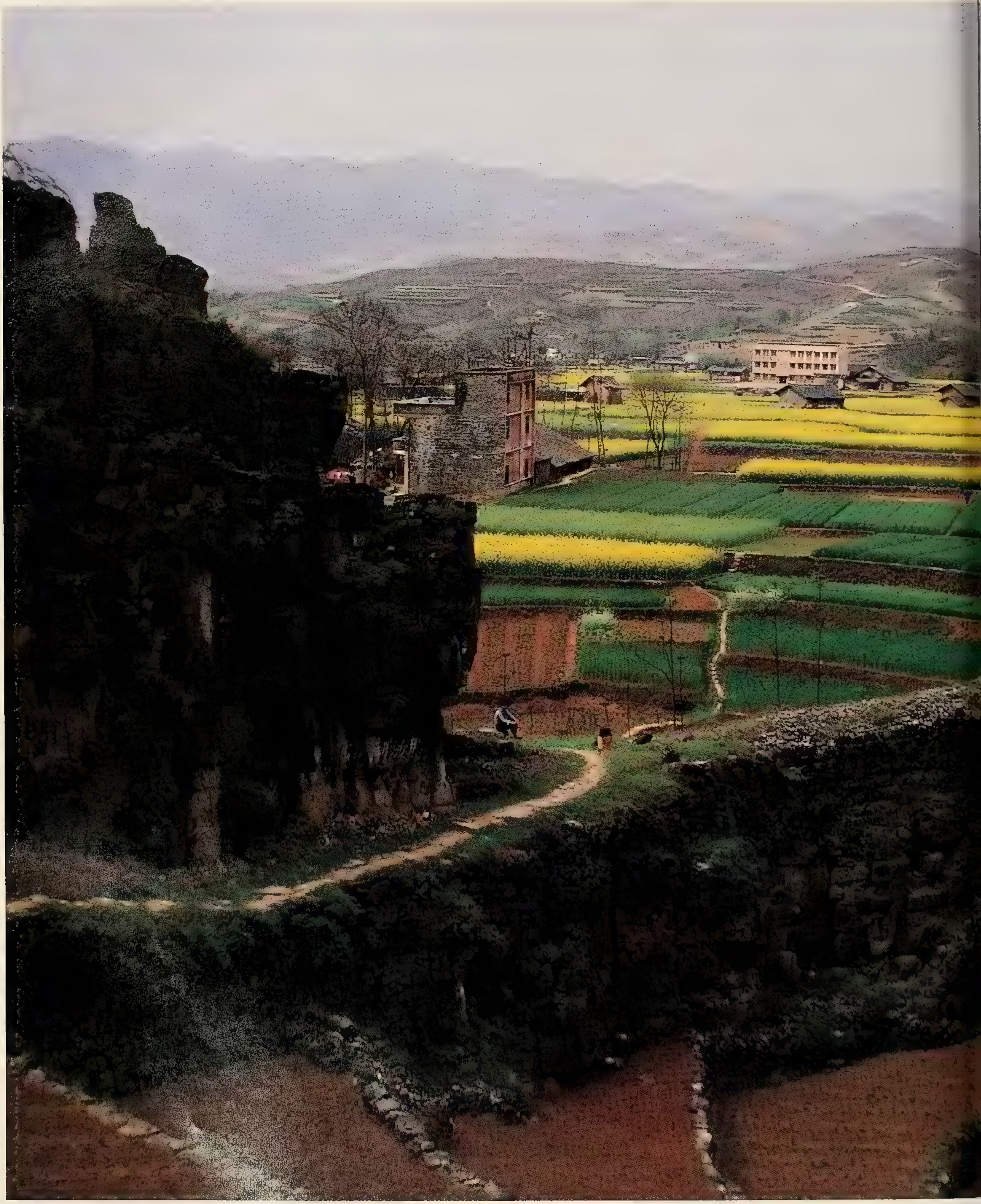
After a kid has been lightly spiced with a simple salt and pepper rub, the whole *cabrito* is skewered on a long metal rod, which is rotated just close enough to the fire to cook the meat and crisp the skin That is known as *cabrito al pastor*, "kid in the style of the shepherd." In the heart of Mexico, goat is usually steamed in aromatic leaves or stewed in a sauce. Short on water and lacking the leaves used for cooking, the Spanish shepherds of Northern Mexico and South Texas came up with a method better suited to the desert: roasting the kid on a spit over an open mesquite fire.

The trick to *cabrito al pastor* is to turn the spitted kid close enough to the fire to crisp the outside, while charring the bones as little as possible. The waiter points out the cuts. The *pierna* is the juicy thigh portion; the *paleta*, the dry and crispy shoulder blade; and his personal favorite, the *riñonada*, the lower loin portion near the kidney. I ask for a little bit of each.

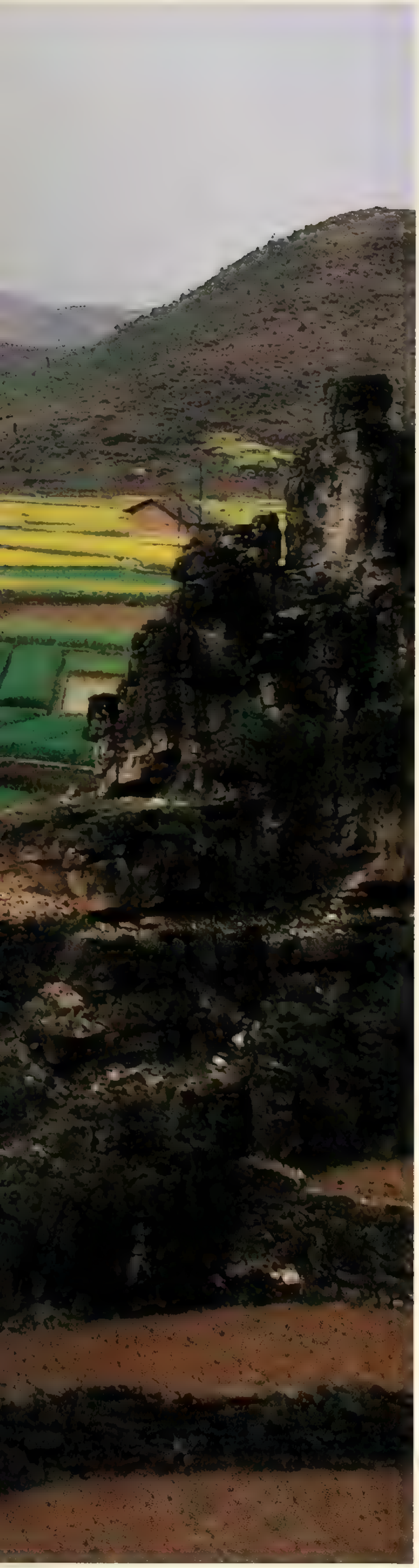
When the dish comes to the table, the first thing I notice is the smell. Goat meat has an acrid, gamy aroma, although the juicy meat is tender and surprisingly mild. The *cabrito* has all the strong character of meat cooked on an open flame—crispy outside, juicy, flavorful meat inside, and the smoky taste and aroma of the wood fire. The *riñonada* is fabulous. The white loin meat along the spine pulls away in long, tender pieces. Attached to the bone are several ribs; I pull them apart and enjoy the tidbits of meat in between and the thin, crispy meat that covers them.

It's a long way to go for a perfect goat rib. Unfortunately, if you're hoping that the increased sales of goat meat in New York means that fabulous goat ribs like these will soon be available at upscale eateries, I'm afraid you're out of luck. A few fancy restaurants have experimented with goat meat, but the vast majority of goats exported from Texas and elsewhere to New York are being bought by new immigrants for whom goat is bound up with tradition. Curried goat, for instance, is popular with Jamaicans. In some Haitian religious ceremonies, goat is sacrificed and then consumed; and Muslims celebrate Id-al'Adha by sacrificing goats in the tradition of the sacrifice made by Ibrahim (Abraham).

Driving home across the Mexican ranchlands, I am feeling a little nostalgic for a part of my own culture. On a hillside above the highway, I watch a man on horseback ride through a tiny village's dusty dirt roads. The houses are surrounded by prickly pear fences. Someone is sitting on the steps in front of the cantina. There are no helicopters in sight. And I imagine you can still find a hitching post here when you need one. ☐



Viewed from the hilltop above Longgupo Cave, cultivated fields spread out toward the village of Miao-yu.
Photographs by Russell L. Ciochon



The Earliest Asians Yet

A trip up the Yangtze brings news of unanticipated fossil discoveries

by Russell L. Ciochon

The diesel-powered packet boat pushed against the sediment-charged current of the Jinsha Jiang (Yangtze River), which flowed swiftly through narrow gorges. Perched above the river's high-water mark, small villages nestled along ridges at the base of limestone towers or in niches along the steep walls. Archeologist Roy Larick, geochemist Chas Yonge, and I (a paleoanthropologist) were in this corner of central China in March of 1992 to explore caves containing deposits with the fossil remains of extinct mammals that inhabited this region millions of years ago. We had begun our river journey at the port of Yichang, accompanied by Chinese paleoanthropologists Huang Wanpo and Gu Yumin, who had invited us to undertake archeological and geochronological surveys of their sites. After a ten-hour journey upstream, we reached Wushan, in eastern Sichuan, the jumping-off point for our expedition. As our vessel coasted to the dock, throngs of porters crowded aboard, competing for the job of carrying our bags ashore.

Owing to the low water level at this time of year—prior to the heavy rains of late spring and summer—we had to cross four gangplanks and then climb a long series of stone steps to reach the town. A man who had been on the boat with us ran up the stairs, dangling a string of exploding firecrackers. Following him were three somber men carrying a cloth-wrapped corpse on a bamboo litter. Close behind, five women, their arms linked, wailed and gesticulated. Traveling with the body of their relative, they, too, had made the river journey.

After a week's stay in Wushan, we crossed the river by ferry and headed south in a four-wheel-drive vehicle, passing through blooming, golden-hued fields of rape, an early Chinese domesticate still harvested for the oil in its seeds. Our destination was Longgupo (Dragon Hill) Cave, whose excavation by Chinese scientists had yielded stone artifacts, some remains of early humans, and the teeth of *Gigantopithecus blacki,* the largest primate ever to roam the earth (*see* "The Ape That Was," by Russell L. Ciochon, *Natural History,* November 1991).

We were following in the footsteps of paleontologist Walter Granger, who explored this region as a member of the American Museum's Central Asiatic Expeditions from 1921 to 1926. But Granger's first trip up this river was considerably more perilous than our own. Not only was the river's course swifter and more dangerous at that time, owing to the lack of dams and locks, but Granger had also steamed into the middle of an interprovincial war. The Sichuanese army, which had invaded Hubei Province, was trying to seize the river port at Yichang, just below the Yangtze Gorges. At Yichang, the river is more than a half mile wide, and Granger's steamer—surrounded by American, British, and Japanese gunboats—was anchored offshore. When fighting broke out, Granger was able to watch the Sichuanese swoop down on the Hubei defenders from limestone pinnacles and cliffs 500 feet above the river:

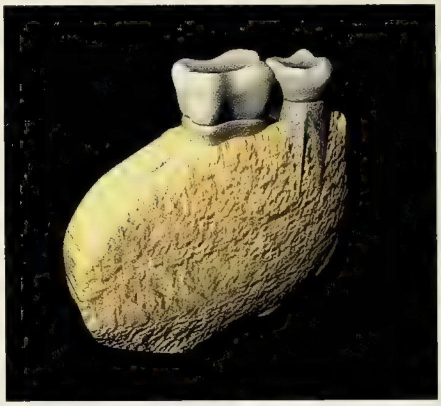
> The defenders who had been holding this ridge opposite Ichang [Yichang] were driven off it before our eyes. Some of them managed to get into ravines between the pinnacles and reach the water's edge by steep trails, but many were actually pushed over the sheer face of the slope and rolled down to the water's edge, either killed by the fall or drowned as they plunged into the river. . . . I remember observing the first onslaught through my porthole while shaving shortly after daybreak, and the observations were continued through the saloon windows while at breakfast and later from the upper deck of the steamboat. *(The New Conquest of Central Asia,* 1932)

Just as Yichang was about to fall to the invaders, reinforcements headed by General Wu Peifu arrived from the capital, and the city was spared.

Two and a half hours after leaving Wushan, we pulled into Miao-yu, a village of 500 that would be our base of operations. Dating from the Ming dynasty, the village sits at the end of a karst valley rimmed by limestone peaks. Once we had greeted and thanked our local hosts, we headed off on foot to the south, following

Unexpected Company

Originally identified by Chinese scientists as belonging to a new subspecies of *Homo erectus* (a human ancestor already known from Asia), a fragment of lower jaw discovered at Longgupo Cave, Sichuan, shares features with two East African hominids, *H. habilis* and *H. ergaster.* As in *H. habilis,* the two principal cusps of the premolar (the smaller tooth at right) are found at the front of the tooth, and there is a large basin behind the cusps. In *H. erectus,* these two cusps are placed in the center of the tooth, with little or no basin behind them. Another feature of the Longgupo premolar is that it is double-rooted. While this feature also distinguishes it from *H. erectus,* it is characteristic of *H. ergaster,* rather than *H. habilis.* The adjacent molar has five cusps, as in *H. habilis* and *H. ergaster,* whereas the molars of *H. erectus* from Zhoukoudian and Java have six cusps and a wrinkled enamel. The size of these teeth falls below the range for *H. erectus* but is at the lower end of the range for the two African species. Finally, another hominid specimen recovered from Longgupo, an upper incisor, is indistinguishable in both its shape and size from specimens of *H. habilis.*



Rachel Nador; Image Analysis Facility, University of Iowa

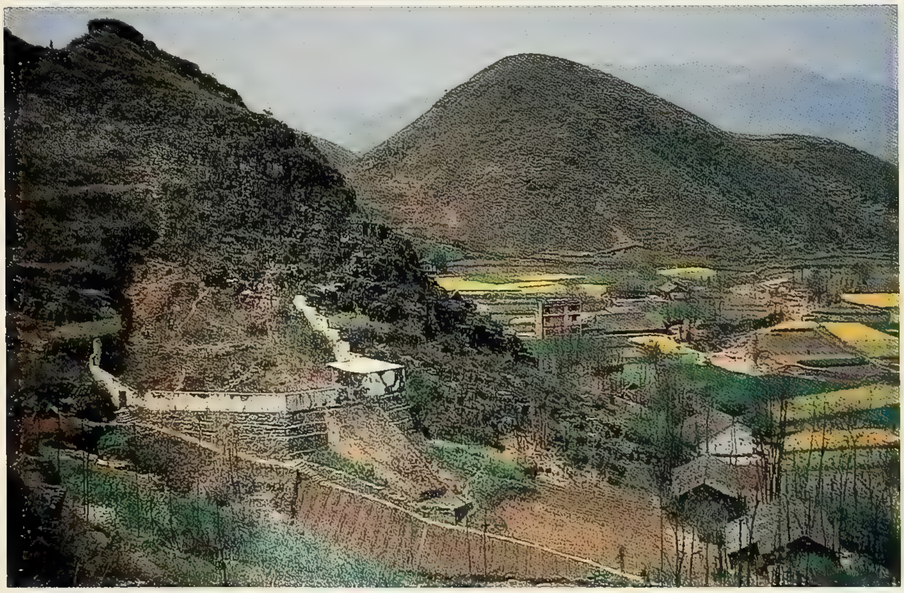
well-worn paths through a checkerboard of green and gold fields. Curious children followed, sometimes darting close enough to get a good look at the foreigners and their field equipment. In the distance we could make out the large opening to a cave in the limestone hillside—but this wasn't Longgupo Cave, which doesn't look like a cave because it is filled from floor to ceiling with accumulated deposits. Nearby the empty cave, we finally saw the entrance to Longgupo. A white-washed wall surrounding the site discouraged unauthorized access.

Longgupo Cave, which passes 140 yards through a limestone formation, first came to the attention of Chinese researchers in 1978, thanks to a report from a local farmer. Farmers along the Yangtze River Gorge sometimes mine fossils and sell them to wholesale merchants who travel up and down the river. The merchants, in turn, supply Chinese pharmacists who have long used such fossils, which they call dragon teeth and dragon bones, as ingredients in potions intended to cure ailments ranging from backache to sexual impotence. Longgupo had largely escaped dragon-bone mining, however, because the limestone ceiling and uppermost walls at its entrance and exit had collapsed many thousands of years ago, obscuring its nature.

The fossils are contained in the sandy clays, mudstones, and gravels that filled the cave after it formed. When Longgupo was surveyed in 1984 by the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing and the Chongqing Museum of Natural History, a number of fossil mammals were recovered, including *Gigantopithecus,* a giant herbivorous ape related to the orangutan, and *Ailuropoda microta* (micropanda), the ancestral form of the giant panda that still survives in the mountains of eastern Sichuan.

In four years, researchers unearthed more than 10,000 specimens of fossil mammals, mostly teeth, as well as about 750 limb bones (usually fragments but sometimes complete). Among them were the extinct mastodont elephant *Sinomastodon* and an early species of horse, *Equus yunnanensis.* Some of these fossils may have accumulated when unsuspecting animals accidentally fell through vertical passages, or "chimneys," in the cave. Others were probably dragged in by large carnivores, such as saber-toothed cats or, more likely, the large hyena *Pachycrocuta,* whose fossils are common at Longgupo. Fossilized droppings (coprolites) from this hyena suggest the cave may have occasionally served as a lair.

Some fragments of long bones show puncture marks and splitting typical of the jaw action of a large carnivore. Many of the bones and teeth were also gnawed by porcupines and smaller rodents (porcupines need the calcium found in bones for their quills). Broken and dispersed, the bones were most likely interred in deposits from a stream that flowed down the valley and through the cave.



Because Longgupo Cave is completely filled with fossil-bearing deposits, the outlines of its entrance (behind the wall) barely contrast with the limestone hillside.

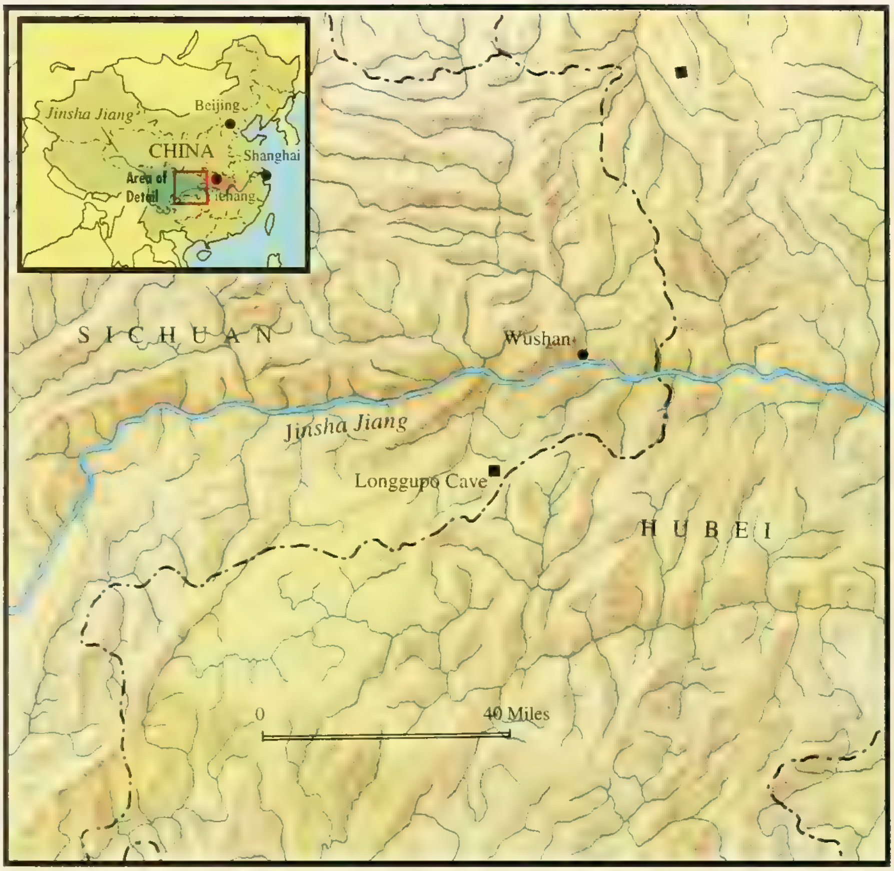
But the most exciting anthropological

discoveries were two fossils of a hominid (a member of the group that includes humans and their close relatives). One was an upper incisor; the other a fragment of lower jaw with a premolar and adjacent molar. Hominid remains of any kind rarely turn up in cave sites with such ancient animal species. The excavators concluded they had discovered a new subspecies of *Homo erectus*, a hominid known to have lived in Asia, and among whose representatives are Peking man from Zhoukoudian, dated about 600,000 years ago, and the earlier Java man from Trinil, Modjokerto, and Sangiran.

Carefully examining stones removed during the excavation, the Chinese scientists found two specimens—a spherical cobble hammerstone and a large battered flake—that appeared to have been shaped or worn through human action. They were made of porphyritic andesite, a type of rock not found elsewhere in the excavation. These stones could not have been washed into the cave because they probably came from rock outcrops downstream from the site. The most likely explanation is that these were tools carried to the cave by hominids.

The first objective of our expedition to Longgupo was to reconfirm the antiquity of the animal fossils from the site and to establish whether the human fossils and artifacts were equally ancient. The Chinese had recorded twenty excavation levels for all the fossils, and they had sampled each level for residual paleomagnetism. Because the earth's magnetic field has reversed direction (from north pole to south pole and vice versa) periodically throughout its history, and the dates of these events are known, the measurement of residual paleomagnetism provides a series of reference dates for the levels. Using this method, the Chinese determined that the hominid remains and the battered flake, which were discovered in levels 7 and 8, were between 1.78 million and 1.96 million years old.

We were able to support this finding through an independent dating technique, electron spin resonance (ESR). For this purpose we collected a deer tooth and surrounding sediment from level 4, about ten feet above levels 7 and 8 (unfortunately, those two levels were too deeply buried for us to sample without major excava-

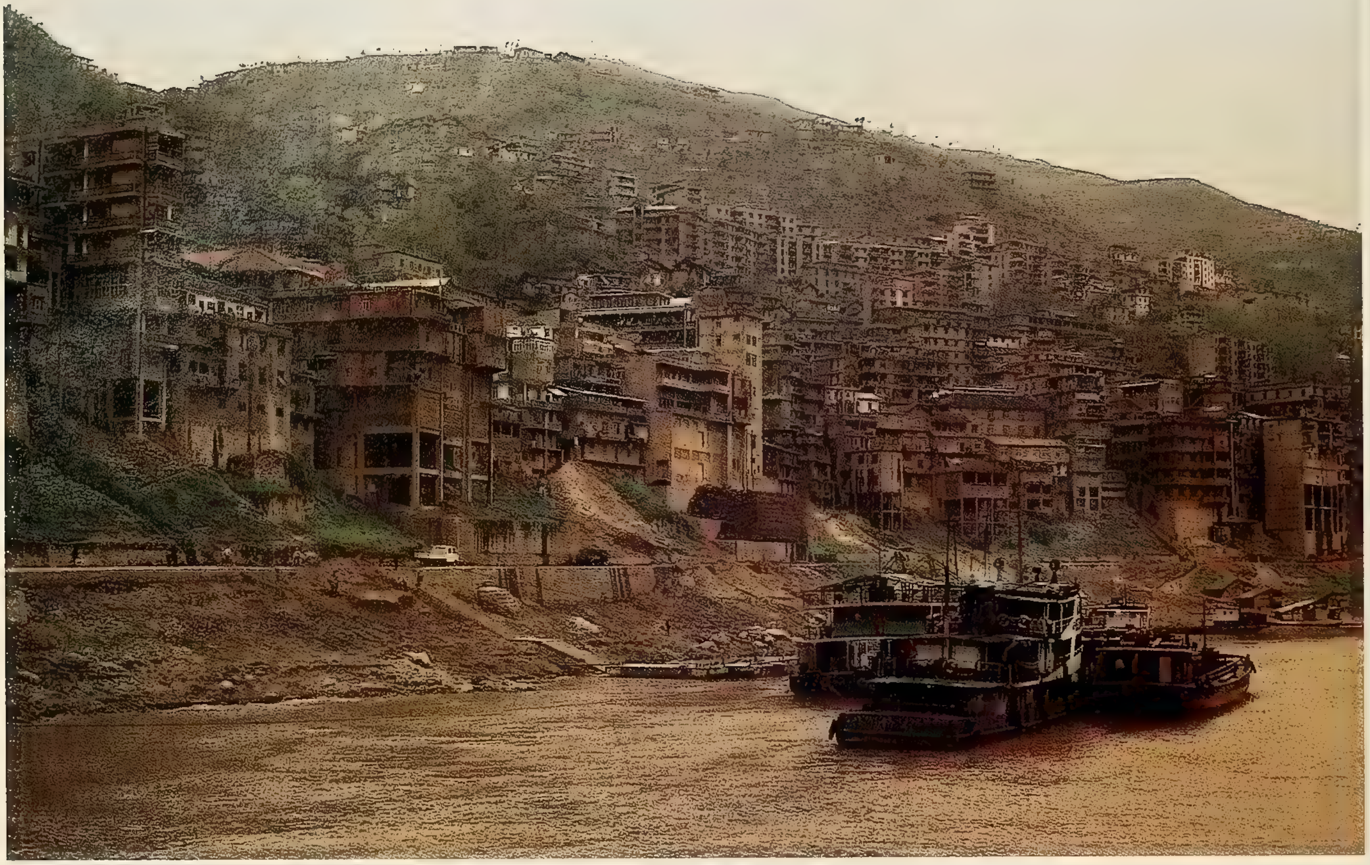


Voyage to Wushan

Longgupo Cave is inaccessible to all but scientists with government permits. But intrepid travelers may be interested in retracing the route of the authors' fossil-seeking expedition, which passed through spectacular gorges along the Jinsha Jiang (Yangtze River). By second-class passenger boat or by cruise ship, you can embark at the port of Yichang and take a ten-hour journey upriver to Wushan, the town closest to Longgupo Cave, and well worth visiting. A bustling river community of about 30,000 people, Wushan crowds the north shore on a meander of the river. Wushan's winding streets and alleyways crisscross the terraced limestone hillside that rises to a vertical slope just behind the town. (Even houses a short distance from the river may have fine views of the gorge and river below.) Some cruise ships bound for Chongqing stop in Wushan only to connect with a motorized sampan that makes day trips up the Daning River through the Three Little Gorges.

If you plan to be in or near Beijing, the Peking man site is in Zhoukoudian, a village about thirty miles southwest of the city. The "apeman cave" is on a hill and other archeological sites are nearby. A fossil exhibition hall at the site features prehuman history, the life and times of Peking man, and recent anthropological research finds. On exhibit are ceramic models, stone tools, and skeletons. Unfortunately, many of the original fossil bones were lost in 1941 during the Japanese invasion of Beijing.

In general, visitors to China are advised to make prior arrangements through a travel agent. China International Travel Service (CITS) or China Travel Service (CTS) tours to the Zhoukoudian site are available but should be booked well in advance. An excellent reference guide for both the tourist and the adventurous, independent traveler is *China: A Travel Survival Kit*, 4th edition, Lonely Planet Publications, 1994. For more about hominids in China, see *The Story of Peking Man: From Archeology to Mystery*, by Jia Lanpo and Huang Weiwen (New York: Oxford University Press, 1990).



The town of Wushan has occupied its position on the north bank of the Yangtze for at least 3,000 years.

tion). Over the hundreds of thousands of years that the deer tooth rested in the cave, it was bombarded by electrons emitted by the traces of radioactive elements present in the sediment. The electrons became trapped in crystals of apatite, a mineral component of teeth. Henry Schwarcz and Jack Rink, isotope geochemists at McMaster University in Ontario, measured the number of trapped electrons and calculated the radiation dose level given off from the sediments. In this way, Schwarcz and Rink were able to date the tooth at 1.02 million years, the expected result for level 4. This absolute date helps corroborate the sequence of paleomagnetic dates in the cave and thus an age for the hominid remains of about 1.9 million years.

The only other Asian hominid sites that are close to this age are two of the Javanese *Homo erectus* localities, Modjokerto and Sangiran, previously thought to be 1 million years old and recently redated to about 1.8 and 1.6 million years ago. But the early date of the Longgupo hominids is not their only intriguing aspect. We found that the specimens share features with two East African early hominids. These are *H. habilis*—known from Olduvai Gorge, Tanzania, and east of Lake Turkana, Kenya—and *H. ergaster,* known from sites around Lake Turkana. Both date from roughly 2.2 million to 1.5 million years ago (*see* "Unexpected Company," page 52). We also realized that the two Longgupo artifacts resemble the "Oldowan" technology of East Africa described by Mary Leakey (no stone tools at all have been found at the earliest *H. erectus* sites in Asia).

The two African species arose from a diversification of early *Homo* species that began about 2.6 million years ago, perhaps in response to climatic change. *H. habilis* was a small species with females reaching a height of perhaps three feet. Relative to its body size, its arms were long, like an ape's, and its teeth were large. *H. ergaster* was larger overall, with females reaching four and one-half feet or more. Its skeletal proportions were similar to those found in modern humans, except for a narrowing of the pelvis. Relative to body size, the brain was larger and the teeth smaller than in *H. habilis*. The implication of the finds at Longgupo is that the first hominid to arrive in Asia belonged to one of these species or a close relative, and that it possessed a stone-based technology.

The existence of this early hominid in China—tentatively *H. habilis*—raises the issue of its relationship to *H. erectus*. One possibility is that *H. habilis* and *H. erectus* were sister species that spread out of Africa in successive migrations. But some paleoanthropologists argue that *H. erectus* is solely an Asian species. If so, this lineage may have evolved in Asia from the species represented at Longgupo. Human dispersal from Africa to Europe and Asia is proving more ancient and more complex than previously thought. Longgupo is one of several new finds that are rewriting our understanding of human evolution in the Old World. □

Field Guide

Recommended travel and reading from the authors of this month's features

Wombats in Australia

(Story page 26)

Hairy-nosed wombats are found on the semiarid plains in the southern coastal region of Australia, from the Murraylands (surrounding the Murray river and its tributaries) in South Australia through the Nullarbor plain into Western Australia. Common wombats live in the forested regions of New South Wales and throughout Tasmania.

In the Murraylands, Brookfield Conservation Park, a reserve established especially for the hairy-nosed wombat, is the best area for sighting the species. Accommodations in the immediate area are available but are not as plentiful or varied as those that can be found in the nearby Barossa Valley, a wine-producing region outside the city of Adelaide.

Common wombats are most easily observed in the Snowy Mountains of the Australian Alps. This resort location also offers skiing and hiking. Both this area and the Murraylands are excellent places for viewing wildlife and flora, especially during Australia's spring, from September through November.

The Complete Book of Australian Mammals, edited by Ronald Strahan (Salem, N.C.: Merrimack Publishers Circle, 1986), is an excellent photographic index of the fauna of Australia. An enjoyable manual for common wombat watchers is *The Wombat,* by Barbara Triggs, with illustrations by Ross Goldingay (Sydney: New South Wales University Press, 1988).

Common wombat
Tom J. Ulrich

Natural-born Mothers

(Story page 30)

For more information on why we call mammals mammals, readers can turn to Londa Schiebinger's *Nature's Body: Gender in the Making of Modern Science* (Boston: Beacon Press, 1995). Is mother love instinctive? Take a look at Elizabeth Badinter's *Mother Love: Myth and Reality* (New York: Macmillan, 1981), the first of a number of recent books to call into question the concept of "maternal instinct." Author Sarah Blaffer Hrdy recommends *Infanticide and Parental Care,* edited by Stefano Parmigiani and Frederick S. vom Saal (Switzerland: Harwood Academic Publishers, 1994), for an up-to-date, authoritative account of the topic, but warns that readers may have a hard time finding the book. A comprehensive bibliography and critique of current topical literature can be found in *The Evolution of Parental Care,* by T. H. Clutton-Brock (Princeton: Princeton University Press, 1991). Historian John Boswell's *The Kindness of Strangers: The Abandonment of Children in Western Europe from Late Antiquity to the Renaissance* (New York: Pantheon, 1989) is an extraordinary work of scholarship, although Hrdy feels the title might more correctly read "The Unkindness of Kin and the Exploitation by Strangers." A trio of books on breast-feeding includes Valerie Fildes's *Breasts, Bottles, and Babies* (Edinburgh: Edinburgh University Press, 1988), a history of infant feeding through the ages; George D. Sussman's *Selling Mother's Milk: The Wet-Nursing Business in France, 1715–1914* (Urbana: University of Illinois Press, 1982), a case study of the economics of wet-nursing; and *Breast-feeding: Biocultural Perspectives,* edited by K. Stuart-Macadam and Katherine Dettwyler (Hawthorne, N.Y.: Aldine de Gruyter, 1995), which combines medical, evolutionary, and cross-cultural approaches.

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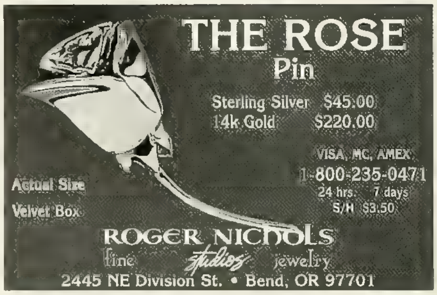

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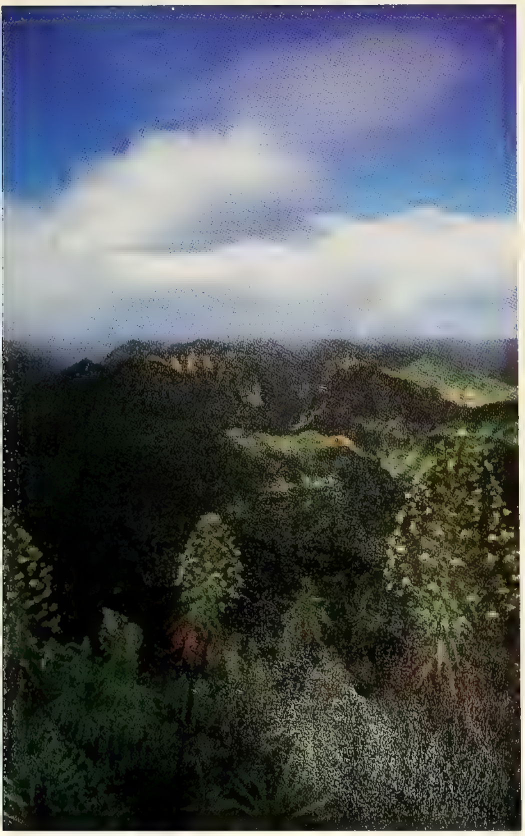
Waimea Canyon to Alakai Swamp, Kauai, Hawaii

by Robert H. Mohlenbrock

The Hawaiian Archipelago consists of 132 islands of various sizes distributed over a 1,500-mile-long swath of the Pacific Ocean. The islands were created by a volcanic "hot spot" that became active seventy million years ago. Because the ocean floor has crept gradually northwestward over the hot spot, the earliest islands to form lie at the northwest end of the archipelago, while the youngest lie to the southeast. Through millions of years of erosion, the oldest islands have been worn down to atolls and shoals. These include Kure, Midway, Pearl, Hermes, Lisianski, and Laysan. Those next in line, worn down to small, rocky pinnacles, include the tiny Gardner Pinnacles and the French Frigate Shoals. The largest landmasses lie to the southeast, with the big island of Hawaii still growing with each new volcanic eruption.

Iliau blooms, below, in Waimea Canyon. Right: Puuo Kila Lookout affords a view of Kalalau Valley.

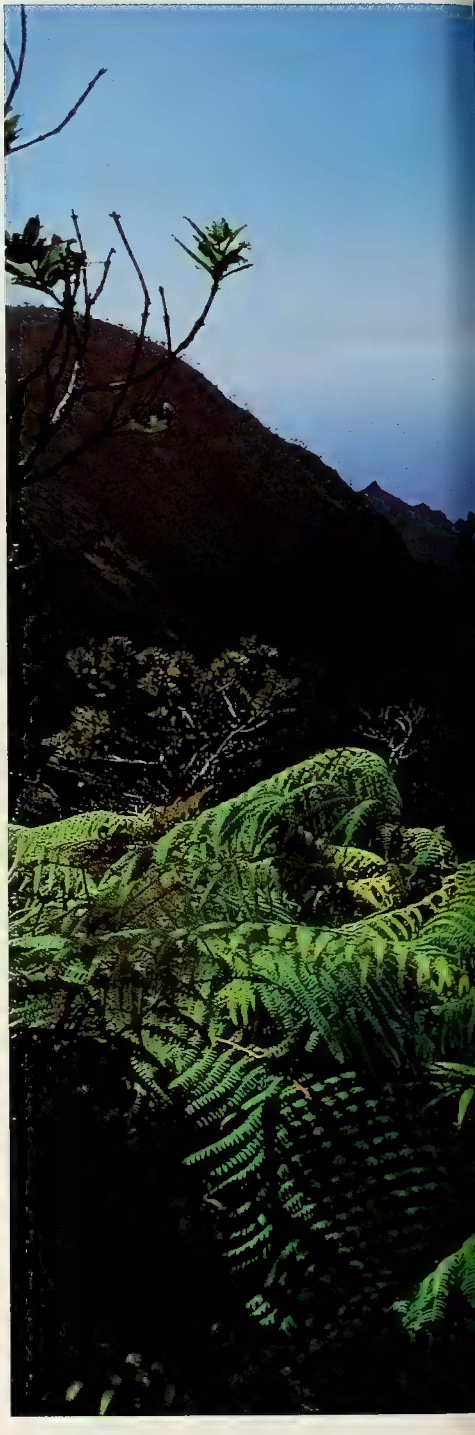


Greg Vaughn

Because the plants and animals that originally colonized these volcanic islands were long able to evolve in relative isolation, the majority of the native species are unlike those found anywhere else in the world. But with human settlement, beginning with the arrival of Polynesians some 1,600 years ago, habitats have been altered. Kauai, the best preserved of the larger islands, is also the oldest, created about five million years ago. It retains more undisturbed areas and unique flora, earning its nickname, the Garden Island.

Kauai has a large central volcanic dome—Mount Waialeale—and a few secondary domes, all deeply cut by lush green valleys and colorful canyons. At 5,080 feet, the top of Mount Waialeale is almost always enshrouded in clouds. It is one of the wettest places on earth, with an annual rainfall of 400 to 600 inches. The mountain's eastern, windward side, which receives more rain than the lee side, has been carved into spectacular green cliffs and valleys.

Cloud forest covers the highest mountain tops, with several extensive high-mountain boggy areas. Below the cloud forest is the montane rain forest, while valley bottoms contain a lowland forest. Marshes once occupied the lowlands of the north coast, but for the most part these have been converted into taro fields. On the drier, western side of Kauai are deep, arid canyons with grassy slopes and sparse, shrubby vegetation.



For a quick overview of Kauai, nothing beats a one-hour helicopter ride with Chuck DiPiazza, who owns and operates Air Kauai. DiPiazza flew me and my wife over and around the coastal cliffs and volcanic mountains and deep into the island's valleys, sharing his love for Kauai, describing its history and features. We listened to his commentary over state-of-the-art Bose headsets, which blocked out the noise of the helicopter. The spectacular tour was all choreographed to the music of Vangelis, which would swell as we came to a mountain crest and then wane as we gently descended on the other side.

A day trip across the western side of

Jon Ogata; Photo Resource Hawaii

Mount Waialeale, through Waimea Canyon State Park and Kokee State Park, with a sampling of Alakai Swamp, provides a more down-to-earth sampling of Kauai's landscape. An excellent highway wends its way up from the southern communities of Waimea and Kekaha and follows the western edge of Waimea Canyon. From several places, one can peer into the canyon, known as the Grand Canyon of the Pacific. Roughly ten miles long, one mile wide, and up to 3,600 feet deep, it gleams with ever changing reddish hues as the sun passes overhead.

Not far into Waimea Canyon State Park the road comes to the Iliau Nature Loop, an easy, short trail that provides a brief look at some of the canyon's vegetation. Growing near the beginning of this trail is the iliau plant, for which the trail is named—an unusual-looking shrub consisting of a rather spindly woody stem topped off with a cluster of a dozen or so sword-shaped leaves. The stem itself is ringed with the scars left by leaves from previous years. When the plant is several years old, cream-colored flower heads de-

Jack Jeffrey; Photo Resource Hawaii

An apapane perches in an ohia lehua tree, which may grow close to the ground or more than 100 feet tall, depending on local conditions.

velop at the top in a two- to three-foot-long spray. As many as 500 individual flowers are crowded into each flower head.

There are only two kinds of iliau in the world, both found only on Kauai (a smaller, rarer dwarf iliau is found on the northwest coast). Iliau belongs to the aster, or sunflower, family and is closely related to the equally strange-looking, but better known, silverswords, which grow on Maui. The genus is *Wilkesia,* named for Captain Charles Wilkes, who commanded the United States' Exploring Expedition to Hawaii in the midnineteenth century.

A little farther along the Iliau Nature Loop are some slender shrubs with heart-shaped leaves clustered near the ends of the branches. These are true violets, giving rise to typically shaped, purple-tinged white flowers.

There are occasional small examples of two of the most characteristic native trees of the Hawaiian Islands, koa and ohia lehua. Koa, a type of acacia, has beautiful wood that can be fashioned into art objects and furnishings. Ohia lehua (*Metrosideros polymorphus* of the eucalyptus family) is barely fifteen feet tall along the dry Iliau Trail but under optimal conditions may grow more than one hundred feet tall, making it valuable as a source of lumber. Its leathery, smooth-edged leaves come in so many shapes that botanists once thought that there were actually several species of ohia lehua.

Farther along the ridge road, between mileposts ten and eleven, the state has provided access to a marvelous overlook of Waimea Canyon. From this vantage point you can see three spectacular side canyons that come down from the Alakai Swamp. The water that drains down these side canyons forms the Waimea River, which flows through the bottom of the gorge.

After leaving the rim of the canyon, the road continues north into Kokee State Park. After passing the restaurant and museum, which contain gift and book shops, the road passes the Kalalau Lookout before ending at Puuo Kila Lookout. This last overlook, if the clouds cooperate, affords an unexcelled view of Kalalau Valley, the tops of the coastal cliffs, and the Pacific Ocean beyond. The terrain is so steep that there are no trails connecting the overlook to Kalalau Valley. The only access to the valley is from the coast, by a hiking trail from the northeast or by boat.

Puuo Kila Lookout offers a chance to observe the small native birds that flitter incessantly in and out of thirty-foot-tall ohia lehua trees. Sure to be seen are the crimson and black apapane and the greenish amakihi. Less common are the vermilion and black iiwi and the less colorful elepaio. These birds are drawn to the ohia lehua trees by powder-puff clusters of red flowers.

Off the parking area is the head of the Pihea Trail, which winds through the area for several miles. I recommend following it along the rim of the Kalalau Valley to the junction with the Alakai Swamp Trail, and then proceeding into the swamp. For their own safety—and to prevent damage to the fragile plant life—visitors are cautioned not to stray off the boardwalk that is provided part way into the swamp.

Alakai Swamp is thirty square miles of boggy terrain nestled in a depression of Mount Waialeale. Here lava has accumulated in layers that erode very slowly, so water from the heavy rains on the mountaintop drains only slowly, forming very boggy and muddy terrain. Hummocks of dense sedges and mosses are scattered in the swamp. The sedges include a beaked rush (*Rhynchospora*), a caric (*Carex*), and an unusual mound-forming sedge known simply as *Oreobolus*. Peat from these and other plants has accumulated because the waterlogged soil prevents the breakdown of dead vegetation.

The ohia lehua tree, which grows thirty feet tall at the head of the Pihea Trail, carpets the ground with its leathery leaves and red tufts of flowers in parts of the Alakai Swamp. Two other low-growing shrubs may be nearby—one a type of

Waimea Canyon State Park, Kokee State Park, and Alakai Swamp

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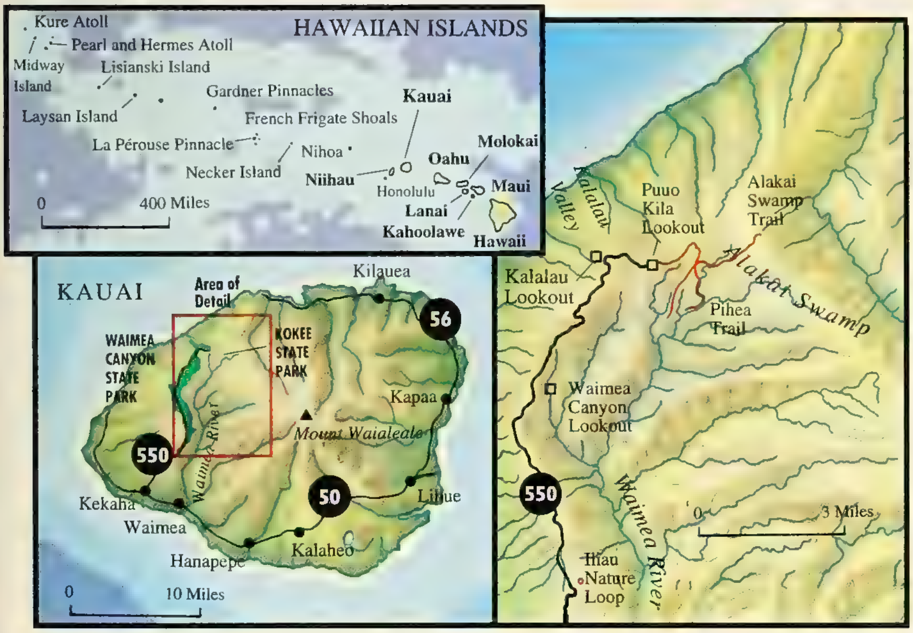
blueberry; the other, called pukiawe, a plant with crowded leaves and red or pink fleshy fruits. None of these three woody species grows taller than four inches under these boggy conditions.

Two aromatic wood species appear along the trail. Mokihana is a small tree with leaves and fruits that smell of anise. Maile is a vine with fragrant leaves whose milky sap shows it to be in the dogbane family. The maile vine is often woven with strings of mokihana fruits to make leis, the characteristic Hawaiian wreaths worn around the neck. Another tree, lapalapa, has leaflets borne in clusters of three, which not only resemble leaves of quaking aspen but also quake with the slightest breeze. Lapalapa is related to devil's walking-stick, a small tree found in the eastern United States.

A lobelia, pue, that grows in the swamp has a woody stem up to three feet tall and up to three inches in diameter, in contrast to lobelias elsewhere in the United States, which are nonwoody wildflowers. A dense rosette of six-inch-long leaves grows at the tip of this plant's unbranched stem, and its two-inch-wide flowers are yellow with purple veins. Other curious plants in the swamp are nohoanu, a woody geranium whose flowers are white with a purple tinge; ape-ape, a ten-foot-tall, nonwoody species with gigantic circular leaves and numerous small flowers; laukahi kuahiwi, a bog-inhabiting plantain that, except for its brown, woolly flower stalk, resembles the broad-leaved plantain that is a weed in lawns and disturbed places in the remainder of the United States; and the Waialeale lily, which has long, folded, silvery leaves and bears flowers with six dark purple petals.

The Alakai Swamp has long been a mecca for birds, particularly honeycreepers, such as the anianiau, a yellow bird with a slightly curved bill; and the rarer akikiki, or Kauai creeper (a gray and white honeycreeper). Unfortunately, diseases from imported domestic fowl and gradual loss of native habitat have caused the extinction of one species and brought several others near the brink. Very rare are the Kauai o-o, a sooty black, eight-inch-long honey eater; the nukupuu, a bright yellow honeycreeper with a short, curved bill; the ou, with its yellow head and short, pink bill; the kameo, or large Kauai thrush; and the puaiohi, or small Kauai thrush. Gone is the Kauai akialoa, a yellow honeycreeper with a two-and-a-half-inch-long curved bill that could penetrate the tubular flowers of the lobelia.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the U. S. national forests and other parklands.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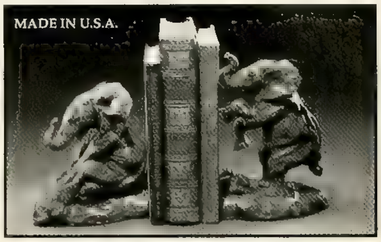

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High Tides

by Joe Rao

Although the new moon will be invisible to us, lost in the blinding rays of the sun, its effects in December should be evident to those living in coastal areas. Because of its timing, this month's new moon (on the 21st at 9:22 P.M., EST) nearly coincides with perigee—when the moon makes its closest approach to the earth—and some of the highest and lowest tides of the year are expected. Less than eight hours after new moon, at 5:00 A.M., EST on the 22d, the moon will be about 221,800 miles from the earth: closer to us than at any other time this year, and within some 400 miles of its closest possible approach. (Because the moon travels in an elliptical orbit around the earth, its distance from us can vary by as much as 31,000 miles—enough to noticeably alter its day-to-day influence on the tides.)

During new and full phase, the moon and sun align with the earth, so that the gravitational pull of both bodies are combined. Although the tidal effects of the sun are only 44 percent as strong as those of the moon, when the two are added together, they produce significantly higher tides, called spring tides (a term that has nothing to do with the spring season but rather with the water's appearing to "spring" from the earth).

All bodies of water, large or small, are subject to the tide-producing forces of the sun and moon. (Tides also occur in the solid earth and in the atmosphere, but the displacements are small and can only be detected by sensitive instruments.) In inland bodies of water, the regular rise and fall of the tide is so small that it is completely masked by water-level changes caused by wind and weather. Lake Superior, for example, has a tide that rises and falls only about two inches. Only along coasts where oceans and continents meet are tides great enough to be noticed. Such effects are most pronounced where funnel-shaped estuaries and bays magnify tidal effects. In Canada's Bay of Fundy, for instance, the difference between high and low tide is sometimes more than fifty feet.

This month's "perigean spring tides" could lead to coastal flooding, especially if they happen to be accompanied by a storm with winds blowing water onshore. If, for example, strong east-to-northeast winds occur along the East Coast of the United States on or near December 22, widespread flooding could take place, especially in low-lying areas.

THE PLANETS IN DECEMBER

Mercury becomes a naked-eye evening object in the latter half of the month, creeping back onto the evening stage in easy view for northerners and setting more than one and a half hours after the sun at year's end. Mercury will be nearly two magnitudes brighter than Mars on the 23d, when these two planets pass about a degree from each other very low in the west–southwest sky after sundown.

Venus grows much more conspicuous as the month progresses and climbs rapidly higher in the southwest. By the end of December it lingers for some two and a half hours after sunset. On the evening of the 23d, the crescent moon sits well off to the right of Venus; on Christmas Eve, the moon will hover directly above this brilliant planet.

Mars, in Sagittarius, appears fainter than a first-magnitude star and becomes increasingly difficult to see as it sets close to the end of evening twilight. Even with binoculars, you might have difficulty finding Mars on the 23d, when it sits just to the right of Mercury.

Jupiter is hiding on the other side of the sun this month, reaching conjunction on the 18th.

Saturn, looking like a yellowish white first-magnitude "star" in Aquarius, is in the south at sunset and sets near midnight. Saturn's appearance through a telescope is much as it was in late November, with the rings apparent only as a dark band across the disk of the planet (although the darkened rings are a little narrower). A thickening crescent moon will be above and to the right of Saturn on the evening of the 26th, and above and to its left on the evening of the 27th.

The **Moon** is full on the 6th at 8:27 P.M., EST. Last quarter is on the 15th at 12:31 A.M., EST. New moon occurs on the 21st at 9:22 P.M., EST, and first quarter on the 28th at 2:06 P.M., EST.

The **Geminid Meteor Shower**, which routinely puts on an excellent show, is at its maximum on the night of December 13-14. Under a clear, dark sky, seventy-five "shooting stars" per hour can usually be seen. Unfortunately, this year the bright light from a waning gibbous moon will obscure all but the brightest meteors. The best time to watch the show will probably come before local moonrise at approximately 11:00 P.M. The meteors are called the Geminids because they appear to emanate from Castor in Gemini, which will be rising out of the northeast sky during the early evening hours.

The **Winter Solstice**, marking the beginning of winter in the Northern Hemisphere, occurs on December 22d at 3:17 A.M., EST. At this time, the sun's direct rays are shining farthest south of the celestial equator, namely, on the Tropic of Capricorn (latitude 23.5° south). While plenty of cold days lie ahead, the days will now begin to grow longer.

Meteorologist Joe Rao is a guest lecturer at the American Museum-Hayden Planetarium.

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Continued from page 15

large boughs attached to the trunk (phyla such as Arthropoda and Chordata); smaller units as branches attached to the boughs (classes like Mammalia and Aves joined to the chordate bough); and, finally, basic units as twigs attached to branches (species like *Homo sapiens* and *Gorilla gorilla* attached to the primate branch of the mammalian bough of the animal trunk). This topology works splendidly for objects produced in a system of branching evolution with continuous divergence and no later joining of separately formed branches. Since the history of life operates by this geometry, the Linnaean system is ideal for classifying organisms.

Second, basic units must be discrete and definable, not smoothly intergrading and constantly joining. Since organic species are discrete and stable units (after the brief geological moment of their branching origin), the Linnaean system also works splendidly for complex, sexually reproducing organisms.

But the same reasons that allow the Linnaean system to classify fossil organisms so well also guarantee an inapplicability in principle to the two categories of the mineral kingdom that Mendes da Costa's age also called "fossils"—minerals and rocks. Minerals and their crystals have definite chemical formulas and aggregate by simple physical rules. Their relative similarities are not genealogical, and their order cannot therefore be expressed by a treelike geometry. Moreover, mineral "species" are not discrete entities composed of genealogically related individuals in historical continuity. Cambrian quartz, at half a billion years of age, does not differ from Pleistocene quartz separately made in a geological yesterday.

Rocks and soils, composed of mineral grains and their erosion products, fail the Linnaean requirements for an even more fundamental reason. Rocks and soils form a broad continuum of fully intergrading compositions. We cannot identify discrete species of granites, marbles, or chalks. Granites, for example, are composed of quartz, two kinds of feldspar and a dark mineral like biotite or hornblende—and all these constituents can be mixed and matched like housepaint into any desired composition.

Nonetheless, Mendes da Costa, as a devotee of the classical passion for order, struggled to do as the master Linnaeus had enjoined—to make every object of nature fit the binomial system, thereby bringing all phenomena into one grand arrangement. Thus, in *The Natural History of Fossils,* Mendes da Costa presents a Linnaean classification of earths and stones into species, genera, and other categories now used only for organisms. His great treatise has a wonderfully archaic ring today because he seems to treat objects of the mineral kingdom as a collection of organisms, and he sets, as his highest goal for this part of geology, a grouping of rocks to match a listing of beetles. I am particularly fond of Mendes da Costa's *Natural History of Fossils* because this treatise, more than any other work written in English, records a short episode expressing one of the grand false starts in the history of natural science—and nothing can be quite so informative and instructive as a truly juicy mistake .

I am no Freudian, but one certainly glimpses Oedipal feelings in Mendes da Costa's attitude towards Linnaeus.

Consider Mendes da Costa's classification of earths and stones. He does not use all of Linnaeus's names for categories, but his basic procedure does not differ. Linnaeus's hierarchy included four levels (we have since added several more): class, order, genus, species. Mendes da Costa uses six: series, chapter, genus, section, member, and species. At the highest level, he divides his geological objects into two series: *earths* and *stones*. Following the Linnaean principle (and a long history of Western thought traceable to Aristotle), he provides a diagnosis of differences based on a *fundamentum divisionis*. Earths are "fossils not inflammable, but divisible and diffusible, tho' not soluble in water"—whereas stones have the same properties, but are not divisible and diffusible.

He separates *earths* into seven genera within three chapters. Chapter 1, defined as "naturally moist, of a firm texture and which have a smoothness like that of unctuous bodies," includes three genera—boles (*Bolus*), clays (*Argilla*), and marles (*Marga*). Chapter 2 ("naturally dry or harsh, rough to the touch and of a looser texture") encompasses two genera—chalks (*Creta*) and ochres (*Ochra*). Finally, Chapter 3 ("naturally and essentially compound, and never found in the state of pure earth") also includes two genera—loams (*Terra miscella*) and moulds (*Humus*).

The second series of *stones* includes nine genera in four chapters, based on interesting criteria that we would now regard as partly superficial and partly on the mark for wrong reasons. The four chapters cover (1) stratified rocks made of grit (basically sandstones, divided by Mendes da Costa into two genera for finely stratified with many horizontal bedding planes versus massive and blocky), (2) stratified rocks without grit and homogeneous (divided into two genera—basically limestones and slates in modern parlance—by the same criterion of massive versus thinly bedded), (3) marbles (separated as much for their importance to human arts as for any other reason), and (4) crystalline rocks, divided largely by the size of mineral grains into basalts and other finely crystalline rocks, granites, and porphyries.

Mendes da Costa presents an interesting—although ultimately flawed—rationale for why a system that has worked so well for organisms should render equal service to inorganic geology. "It has been by pursuing such natural and simple methods as these, that botany has so eminently raised her head above her sister sciences," he writes, acknowledging Linnaeus's greatest success.

Mendes da Costa recognizes the differences in formation between organic and inorganic objects, but he follows a common scientific conceit in thinking that a uniform system of classification will nonetheless suffice for all: he will engage only in humble and accurate description, not in fanciful theorizing. Differences in causality cease to matter when we cite only the pristine factuality of objective appearances: "I have been very cautious not to indulge a speculative fancy in forming hypotheses or systems, the bodies being simply described, according to the appearances which they exhibit to the senses."

Mendes da Costa then proclaims success because he manages to balance, in a single system of compromises, all the competing schemes of his contemporaries. Such a "golden mean" must yield optimality. Mendes da Costa argues that he has achieved two great balances in his system—first, by finding the "right" number of basic species as a compromise between "splitters," who love to make fine distinctions, and "lumpers," who search for essences and tend to unite objects in their quest for fundamental properties (splitting and lumping are later terms and the dichotomy is overly simple, but this struggle between joiners and dividers has pervaded the history of taxonomy). Mendes da Costa writes: "I have endeavored to reduce this study, hitherto deficient in respect of method, to a regular science, and in the attempt have been careful neither to multiply the species, nor lessen their number, unnecessarily."

In a second balance, Mendes da Costa tries to bring together the two disparate criteria then used to form systems for rocks and minerals: the efforts of his British compatriot John Woodward to base distinctions on observation of overt properties, both exterior and interior ("a method of arrangement founded on the growth, structure, and texture of fossils"); and continental systems based on "essential" properties discovered by chemical experiment (for example, a threefold division according to various changes produced by fire into *calcarii,* for rocks calcined, or turned to lime (limestones and marbles, for example), *apyri* for those unaffected (asbestos and others), and *vitrificentes* for those vitrified to glass (quartz and other silicates). Mendes da Costa tries to bring all systems together by basing primary divisions on observable properties (Woodward's system), and then applying experimental results for refinements:

> I have attentively examined the Woodwardian and Wallerian [continental] systems, and, finding them defective, have presumed to form a new one from the principles of both. I have endeavored to arrange fossils, not only according to their growth, texture, and structure, but also their principles and qualities, as discovered by fire, and acid menstrua, etc. And in this way, I am confident that all the known fossils may be accurately distinguished; whereas, to attempt it by any one system hitherto followed, must occasion a strange confusion.

But Mendes da Costa's efforts were doomed to failure in principle because the causes and properties of rocks violate the requirements of Linnaean geometry. Following the two central fallacies discussed earlier in this essay, Mendes da Costa could neither identify clear species nor form distinct categories in a world of complete intergradation. Biological species are natural populations, distinct by historical continuity and current interaction and unable to interbreed with others. Rock "species" are nondiscrete and intergrading. Ultimately, Mendes da Costa just joined specimens that looked "enough alike"—a sure formula for endless bickering among specialists, for no two will ever agree. For example, he castigates his two great masters, Linnaeus and Wallerius, for designating too few species in the genus *Marmor* (marbles):

> Wallerius, in his *Mineralogy,* and Linnaeus, in his *Systema Naturae,* are extremely confused in regard to this genus of fossils; the former had divided all the marbles into only three species; viz. of uniform, variegated, and what he calls figured marbles . . . the latter has even made them all only varieties of one species; on which I cannot but make this observation, that it is a pity the learned should apply their studies rather to perplex science, than to elucidate it, and instruct mankind.

(I am no Freudian, but one certainly glimpses Oepidal feelings in Mendes da Costa's complex attitude toward Linnaeus—basing his life's work on the taxonomic system of his intellectual father, but then losing no opportunity to razz the master for moral turpitude on a range of issues from the terminology of clams to the number of species of marbles.)

But Mendes da Costa cannot claim final certainty for his own divisions of *Marmor.* He designates eighty-one species, far more than for any other genus of rocks, and clearly to recognize human utility of different colors and patterns, not because nature has fabricated discrete and discoverable "basic kinds."

Equal difficulty and frustration attended Mendes da Costa's effort to establish the higher divisions of rocks and earths—for he encountered complete intergradation between his genera as often as tolerable separation. For example, he frankly states his difficulty in dividing boles from clays, finally admitting that only convention dictates the separation:

> Several authors do not make a distinct genus of the boles, but rank them among the clays; indeed very essential characteristics are wanting to make them different genera, for only the extreme fineness of the particles of the boles is the cause of their being not so ductile or viscid as the clays, insomuch that speaking with propriety, they are only to be accounted very fine clays; I have, however, made them separate genera, as custom hath authorized it.

The human mind, in both arrogance and fragility, loves to construct grand and overarching theories—a fault perhaps more often encountered in our theological than our scientific endeavors. But solutions often require the humbler, superficially less noble, and effectively opposite task of making proper divisions into different categories of meaning and causation. For only then can we build toward generality on a firmer substrate, and without feet composed of the genus *Argilla.* Mendes da Costa, following Linnaeus, tried to bring all nature into one grand system of classification, but principles appropriate for the branching of organisms do not suit the continuities of rocks and earths. How ironic, ultimately, that a system doomed by too much togetherness should be constructed by Emmanuel Mendes da Costa, the only Jewish naturalist of note in eighteenth-century Britain—a man from a culture then defined by separation from a majority committed to the parochial notion that their theology represents the one, true, and only way.

To heap irony upon irony, and to end with a return to the beginning, Mendes da Costa did understand the general principle whereby rocks must be classified differently from organisms. I omitted one line in his critique of Linnaeus's sexual terminology for bivalves (as indicated by the three dots), for these words cite a technical objection, rather than the moral argument then under discussion. In this line, now restored, Mendes da Costa rejects Linnaeus's bivalve names "not only for their licentiousness, but also that they are in no ways the parts expressed." How simple, and how correct! The top of a clam is not the bottom of a person—and supposed visual similarities can only be misleading. Different terms should be used, lest people be lulled into false suppositions about meaningful or causal likeness. Similarly, rocks and organisms require different systems of classification to acknowledge their disparate modes of production—by timeless chemistry versus singular genealogy, by laws of nature and contingencies of history.

But all people form a single, fragile species, a biological unity too much divided by the worst emotional traits of our common nature. Separate the stones from the snakes, but let Emmanuel Mendes da Costa, a Jewish stranger in a strange land, shake hands with his Mad King George—and then, perhaps, "they shall not hurt nor destroy in all my holy mountain"—made, no doubt, of the genus *Granita,* from the Italian for "grain," to signify all the bits and pieces of diverse minerals that come together to form this hard rock of unity. □

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Selling floral temple offerings in Kathmandu, Nepal

Michael Potter

A Spirited Disagreement

Even scientists are superstitious

by Roger L. Welsch

The popular meaning of the word *folklore*—faulty thinking, silly superstition, baseless tradition—is not the way we folklorists use it in our studies. As (ahem) academicians, scholars, scientists, we try to be more objective about the belief systems of others. So, folklorists label traditionally held ideas *beliefs* rather than *superstitions*. There is, after all, some reason to suspect there is accumulated wisdom, even empirical knowledge, in a lot of those venerable belief systems.

Take belief in ghosts, for example, a phenomenon common to a lot of people and a lot of cultures over a lot of time. (If you think I'm stretching the notion, David Hufford goes even further in his introduction to Michiko Iwasaka and Barre Toelken's *Ghosts and the Japanese:* "Ghosts [are] a concept found in all cultures and at all times of which we have any record.") One of the reasons I consider folklore studies a paragon of the sciences is that folklorists consider such things as ghosts.

Back when I was teaching, I had my second-year folklore students do limited fieldwork projects, if at all possible within their own cultural milieus, or subcultures. One young man came to my office after I gave that assignment in class, baffled about where to turn. He told me he was studying science, loved science, believed in science, trusted science, and couldn't imagine that there would be much in the way of folklore he might find in science. "Scientists don't have superstitions," he insisted.

This young man posed a special problem—and opportunity—for me. He was a nice enough guy, but he had succumbed to the arrogance of "omni-science": not just the minor error of thinking science can know all but also the maxigoof of believing science already knows all. How could I make him realize that every area of human experience or endeavor, including technology and science, has its traditions?

"How about working with a traditionally held belief within the scientific community?" I asked him. "Perhaps an idea members of the scientific faculty have that is without obvious scientific basis—something based on personal, emotional inclination rather than empirical knowledge."

"Sounds like superstition to me," he said suspiciously.

"Well, yes, except we don't call. . . ."

"I know, I've heard you say it in class a dozen times: 'the word *superstition* is a pejorative, so we folklorists use the term *belief* instead.' "

"So then, how about something like ghosts?"

He snorted in disbelief. "Not a single person in that entire science building believes there are ghosts. Do you believe there are ghosts, Professor Welsch?"

"I don't know."

"Have you ever seen one?"

"I may have but I'm not sure. But you don't have to go into that for this assignment. Just find out if your scientist friends believe there might be such things as ghosts, nothing more or less."

And that's what the student did. He returned to my office a few weeks later, triumphant. "I told you," he said, handing me his report. "Not a single person in that huge building, in any department, believes there are such things as ghosts. Superstition has no home in science."

"I wonder," I said, pointing out that in this country if you round up a couple of eyewitnesses, you can send someone to death row, and yet there are tens of thousands, hundreds of thousands who not only believe there are such things as ghosts but believe they have seen them. All around the world, in culture after culture, people believe there are ghosts and that they are seen, sometimes on a regular basis. How many eyewitnesses would we have to have, I wondered aloud, before science would assume the rational, agnostic position that there is plenty of evidence something is going on, but that we don't know what it is?

Obviously, scientific truth is not a matter of taking a popular vote, and there is the problem of proving a negative, but my student friend had to admit it was curious how quickly and strongly his faculty had rejected the *idea* of ghosts. And he amazed himself when he came to the conclusion, on his own, that this rejection was not exactly based on the method of science or even its spirit. In fact, he said, wringing his hands and screwing up his brow in mock pain, "It's almost like . . . like . . . superstition!" He spit the word out like an epithet. Or an admission.

"Yes, it is," I said, trying to comfort the lad. "But let's give scientists the benefit of the doubt or at least the courtesy an ethnographer would extend to any resource in any fieldwork problem. They may, after all, be right in their rejection of ghosts. There may be nothing at all but our imaginations at work. Or some other natural phenomenon that we do not yet understand. So, let's not call it superstition, okay?"

"Yeah, I know," he said with resignation. "Belief. Scientists have . . . (gasp, choke) . . . folk beliefs."

"And having conducted this survey, do you now believe there are such things as ghosts?" I asked.

He got his A for the project because he answered without hesitation, "I don't know; I'm a scientist, after all."

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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When Galaxies Collide

by Neil de Grasse Tyson

There are few things more elegant in the universe than a spiral galaxy. Our Milky Way is one. And so is the nearest system of similar size, the Andromeda galaxy. In the history of astronomy, the taxonomy of galaxy shapes has been a cottage industry that has attracted such astronomers as Edwin Hubble of Caltech, who is the father of galaxy classification schemes; Alan Sandage, of the Carnegie Institution of Washington, a student of Hubble's who carried on the tradition with the publication of the *Hubble Atlas of Galaxies;* and the late Gerard deVaucouleurs, of the University of Texas, who expanded the details of Hubble's original scheme in a way that would have made Linnaeus proud.

Astrophysicists are typically not bent on obfuscation, and the basics of our galaxy classification scheme is no exception. Spiral-shaped galaxies are called spiral galaxies. Elliptical-shaped galaxies are called elliptical galaxies. Irregular-looking galaxies are called irregular. And those unclassifiable, peculiar-looking galaxies are called, you guessed it, peculiar. But sometimes the absence of a classifiable pattern is, itself, a pattern. Not until the early 1970s were most peculiar galaxies fully appreciated for what they really are: "train wrecks"—the consequence of a violent gravitational encounter between two or more galaxies. DeVaucouleurs emphasized, however, that a wrecked galaxy has not become a different variety of galaxy, just as a wrecked car has not become a different make of car.

In the study of galaxies, the term *collision* commonly refers to systems that pass close enough to each other for gravity to induce visible changes in their shapes, whether or not they intersect. The primary cause of distortion is the tidal force that each galaxy exerts upon the other. Since galaxies are large, the part of one galaxy that is nearest the other galaxy will experience a much stronger force of gravity than the part that is farther. Galaxies respond to this difference in pull by stretching. Because the two galaxies are in motion, the evolving appearance can be rich with distorted features.

As early as 1941, before the digital computer was invented, the Swedish astronomer Erik Holmberg performed a clever experiment that explored the effect of a close encounter between two galaxies of equal mass. Knowing that the force of gravity drops off with distance in the same manner as the does intensity of light, he performed a tabletop simulation of colliding galaxies with light bulbs and light meters. Holmberg noted in his Abstract:

> The difficulty of [computing] the total gravitational force acting upon a certain element at a certain point of time is solved by replacing gravitation by light. The mass elements are represented by light bulbs, the candle power being proportional to mass, and the total light is measured by a photocell.

By incrementally moving representative chunks of each galaxy, as dictated by the individually measured intensities of light, Holmberg successfully simulated the basics of galactic dynamics.

Holmberg went on to show that tidal forces produced features like elongated arms in such encounters, and that two galaxies can capture each other in the process. In 1955, the Swiss-born Caltech theorist Fritz Zwicky noted that "some galaxies look as though they are being drawn in tidally induced patterns from other galaxies." And by 1966, the Caltech astronomer Halton Arp, Hubble's only other student, prepared a large photographic atlas of peculiar-looking galaxies from the Palomar Sky Survey, a famous photographic study of the sky. As you might expect, Arp titled his collection the *Atlas of Peculiar Galaxies.* The hundreds of striking images triggered an entirely new vocabulary of galaxy descriptors, such as elbows, fingers, and tails, as well as arcs, bridges, loops, rings, and shells. Astrophysicists finally had a data base with which the phenomenon could be critically studied.

In the early 1970s, digital computers were successfully used to model various encounters between galaxies. Yes, astrophysicists became mergers and acquisitions specialists long before it was the fashion on Wall Street. Computer models of stars in colliding galaxies typically reveal a graceful ballet on a cosmic scale, with motions choreographed by the forces of gravity. Moment-by-moment changes in the force of gravity on every part of the galaxies show how stars can be flung to and fro and how powerful tidal forces can elongate and contort spiral arms.

Models are now run routinely on supercomputers, where all manner of collisions are simulated. Interesting variations include fast, face-on collisions and slow-moving side-swipes. Because of their resilient shape, elliptical galaxies make less interesting collision candidates; they simply puff up. Among spiral galaxies, however, it seems that anything is possible. For example, recent measurements of rotation velocities by Vera Rubin, of the Carnegie Institution, show that in some spirals, up to half of the stars revolve around the system backward. The detailed origin of such galaxies remains uncertain, but they are very likely to be the consequence of two oppositely rotating merged systems.

The primary advantage of using a supercomputer lies in the number of pieces you can use to assemble your galaxy. Ideally, your computer galaxy should contain more than 100 billion pieces, with each piece representing a single star. But even supercomputers are not fast enough for this task, so approximations of real galaxies have many fewer pieces than the real things. Holmberg used thirty-seven specially made light bulbs. Nowadays, galaxies with up to 10 million stars are simulated. Fortunately, the salient features of a galaxy collision are well captured by simulations with fewer than the total number of stars in a real galaxy. But what you miss is the ability to follow the evolution of small-scale star formation, the fate of stars within star clusters, and other detailed features within the galaxies themselves. I have no doubt that when super-duper computers are available, every aspect of a selected collision will be deduced from a single simulation.

During the cosmic acrobatics, individual stars easily pass by each other through interstellar space because galaxies are mostly empty, in spite of how packed they look. For example, if there were just four snails running loose in the continental United States for a billion years, then two of them would be more likely to accidentally bump into each other than would two stars during a galactic collision.

While stars plunge in and out of the system, the fluffy clouds of interstellar gas often stick together like hot marshmallows and trigger intense bursts of star formation. Some have suggested that most, if not all, ratty-looking dwarf galaxies are flotsam from the collision between two large galaxies. But even when galaxies do not have a close encounter, the mere presence of a nearby galaxy and its associated gravity can be irritating. Galaxies that have neighbors are up to ten times more likely than isolated galaxies to have unusual activity in their central regions, such as excessive emission in X-rays, the infrared, or radio-waves.

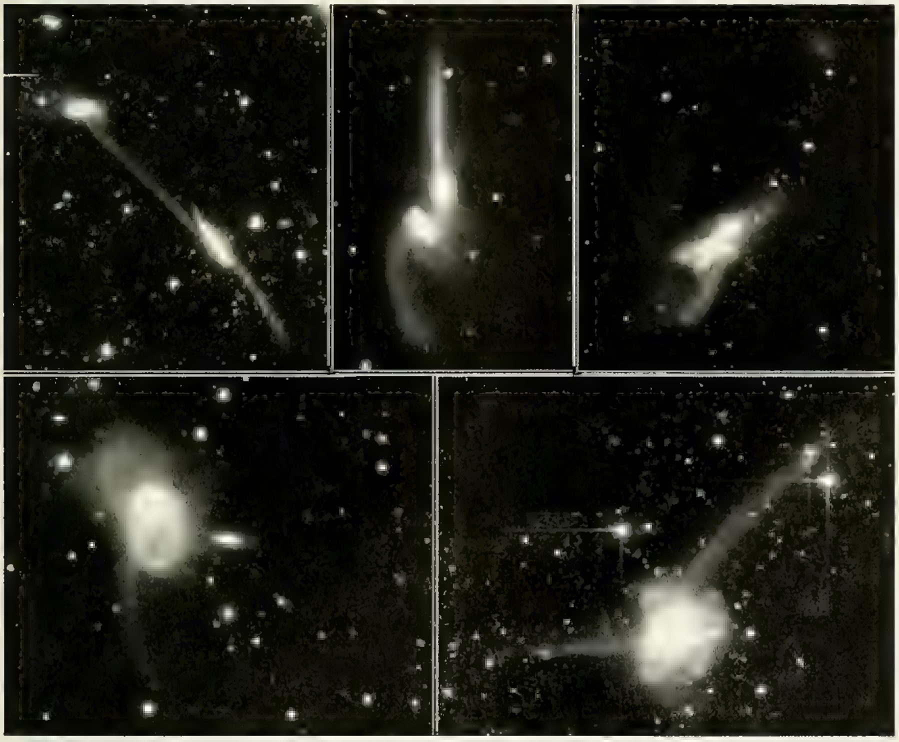
Other compelling evidence suggests that some big galaxies have recently captured little galaxies that wandered too close. The smoking guns are multiple centers within the same gigantic galaxy. Known as galactic cannibals, these galaxies are among the most massive in the universe and tend to be found lurking in the busy centers of rich clusters of galaxies. Indeed, the lessons of the universe sometimes match the lessons of life on Earth: the big get bigger and the small get eaten.

Large galaxies, including the Milky Way and Andromeda, commonly have an assortment of dwarf galaxies in orbit around them. A family photo of the Milky Way would include two fuzzy satellites that are visible from southern latitudes. These galaxies, a small one and a larger one, were described by Magellan during his round-the-world voyage as persistent "clouds" in the sky. In his honor they are officially named—as you might have suspected—the Small Magellanic Cloud and the Large Magellanic Cloud.

If cannibalism is common, perhaps the Milky Way had more than just two satellites in its past. In 1994, R. Ibatha and colleagues at Cambridge University uncovered a set of stars near the galactic center with velocities unlike other stars in their neighborhood. Subsequent models of galactic capture supported Ibatha's conviction that the group of stars is the partially digested remains of a dwarf galaxy that had been swallowed by the Milky Way within the past billion years. Dubbed the Sagittarius Dwarf, had it been eaten much longer ago, the individual stars would have thoroughly mixed with the surrounding stars and the dwarf would have never been discovered. The search is on to find more such systems.

When a colleague of mine who specializes in mathematical models of complex dynamical systems was invited to give a seminar in Italy, he submitted an eye-catching title for his talk: "Mathematical Models of Mayhem." The word *mayhem* is commonly used as a synonym for disorder or pandemonium. The Italians, however, were not familiar with the colloquial use of the term. When they looked it up in a dictionary, they found only the formal definition: the act of intentionally mutilating a person's body so as to cause dismemberment or damage to essential organs. The host queried over the Internet, "Are you sure you wish to use this title?" Of course, my colleague had used the word informally, but a brief look at some of his disturbed, sorry-looking galaxies would indicate that *mayhem* may just be the precise word that describes the scene.

Neil de Grasse Tyson is an astrophysicist with a joint appointment at the Hayden Planetarium and Princeton University. His recent book Universe Down to Earth *(Columbia University Press, 1994) has just been released in paperback.*

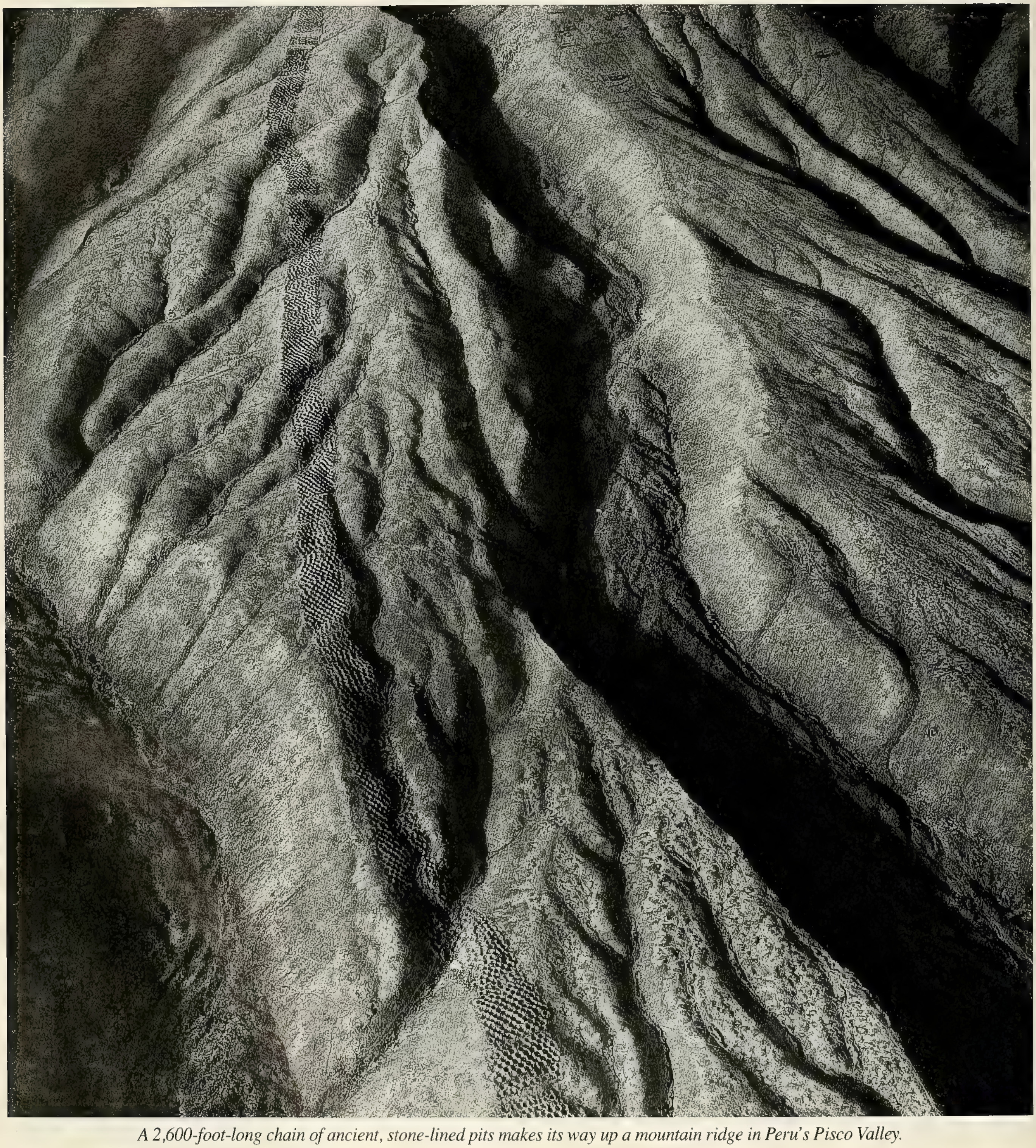


Five galaxy pairs, with their spiral arms severely distorted, are shown in various stages of collision. The images are arranged in order of increasing disorder. In the lower row, both galaxy pairs have almost completely merged.

J. E. Hibbard, Ph.D. thesis, Columbia University

Airborne Archeology

by Craig Morris



Marilyn Bridges

A 2,600-foot-long chain of ancient, stone-lined pits makes its way up a mountain ridge in Peru's Pisco Valley.

Think of archeology and what usually comes to mind? Men and women probing excavations with trowels and dental picks or searching for ancient sites on foot, horseback, or behind the wheel of a rugged four-wheel-drive vehicle. But important archeological research is also done from airplanes, and even satellites.

The work of artist-photographer Marilyn Bridges is a case in point. Bridges has spent almost two decades photographing culturally modified landscapes from virtually every kind of aircraft. Her work combines an exquisite sense of composition and form with an appreciation of the cultural significance of the subjects she photographs. An exhibition of her works opens in early December at the Museum. Many of her most intriguing photographs show archeological sites that document Peru's rich pre-Columbian past.

Bridges was not the first to take aerial photographs in Peru. In 1931, geologist Robert Shippee and ex-Navy pilot and aerial photographer George R. Johnson flew over part of Peru to document Andean landforms, archeological sites, and ancient terracing and irrigation systems. The Special Collections Department of the Museum Library (see *Natural History*, September 1995) acquired hundreds of negatives and prints from this expedition. This was the first time flight was recognized as offering a new way to observe the Andes and the way people had changed them, a tradition continued by modern satellites and spacecraft that relay digital images back to earth.

Bridges, as well as Shippee and Johnson, photographed some of the principal archeological sites of the Chincha Valley on Peru's south coast. A wealthy kingdom of farmers, fisherfolk, and maritime traders had flourished there before the Incas conquered the area in about 1475. According to sixteenth-century Spanish documents, the Chincha traders sailed north in large balsa boats to the warm waters of what is now Ecuador, where they exchanged fine textiles and other goods for spondylus shells. These beautiful red shells of the spiny oyster were considered sacred in the Peruvian region. They appeared only during the rare El Niño years, when warm Pacific waters displaced the colder waters of the Humboldt current off Peru, bringing rain to the coastal desert. Spondylus shells thus came to symbolize the coming of rain and agricultural fertil-

An exhibition of photographs by Marilyn Bridges, entitled "Planet Peru: An Aerial Journey Through a Timeless Land," will be in the Akeley Gallery from December 1, 1995, until February 1, 1996.

DECEMBER EVENTS

The Museum's twenty-fifth annual Origami Holiday Tree will be on display in the Roosevelt Memorial Hall until early January. The fifteen-foot tree will be decorated with 1,500 folded-paper animals, including insects and dinosaurs, created by origami enthusiasts from around the world. For information about origami at the Museum, call (212) 769-5635.

On Monday, December 4, at 7:30 P.M. in the Planetarium's Sky Theater, Richard Gott, professor of astrophysics at Princeton University, will give a talk, "Predictions for the Longevity of the Human Species: A Modern Application of the Copernican Principle." Tickets for the lecture, part of the "Frontiers in Astronomy and Astrophysics" series, are $8 ($6 for members). The Planetarium's annual holiday concert, on Thursday, December 14, at 7:30 P.M., will feature the sixty-piece Elysian Symphony Orchestra playing "planet-inspired" music by Mozart, Gustav Holst, and others. Tickets are $22 ($18 for members). For information about the exhibition of Hayden Planetarium's sixty-year history and other events, call (212) 769-5100.

Throughout the day on Friday, December 29, the Museum will observe the African American holiday Kwanzaa (Swahili for "first fruits of the harvest"). Customarily marked by week-long feasting and the exchange of gifts from December 26 through January 1, Kwanzaa festivities at the Museum will include performances, demonstrations and sales of African crafts, and the re-creation of a traditional African village market. Kwanzaa is part of the Education Department's year-long series, "Multicultural Mosaic: Traditions of a Diverse Society." The program is free with admission to the Museum. For further information, call (212) 769-5315.

MEMBERSHIP PROGRAMS

On Friday, December 1, at 7:00 P.M., Museum paleontologist Niles Eldredge will discuss his recently published book, *Reinventing Darwin: The Great Debate at the High Table of Evolutionary Theory,* which presents the often conflicting views of two groups of evolutionary theorists: geneticists and paleontologists.

Families will be able to sing Hanukkah and Christmas songs with David Grover and the Gang on Saturday, December 2, at 11:00 A.M. and 1:00 P.M.

Storyteller Michael Kusugak will tell tales from the Arctic Circle and demonstrate string games for children (ages 5 and older) and adults on Wednesday, December 6, at 2:30 and 4:00 P.M.

The recent discoveries of extensive Ice Age paintings in two caves in southeastern France, Cosquer and Chauvet, will be the subject of a talk by archeologist Jean Clottes, scientific adviser for prehistoric rock art studies at the French Ministry of Culture. His lecture will take place on Tuesday, December 12, at 7:00 P.M.

Bob Brown Puppet Productions will perform to the music of Camille Saint-Saëns's *Carnival of the Animals* on Friday, December 29, at 11:30 A.M. and 1:00 P.M., in a program for children ages 5 and older.

For details about membership programs, call (212) 769-5606.

The American Museum of Natural History is located on Central Park West at 79th Street in New York City. For more information regarding the Museum's hours and admission fees, call (212) 769-5100.

ity. Spondylus shells were regarded as food for the gods, and people also wore them as adornments. The shells were also ground into a powder that was strewn before the path of important personages during rituals and ceremonies.

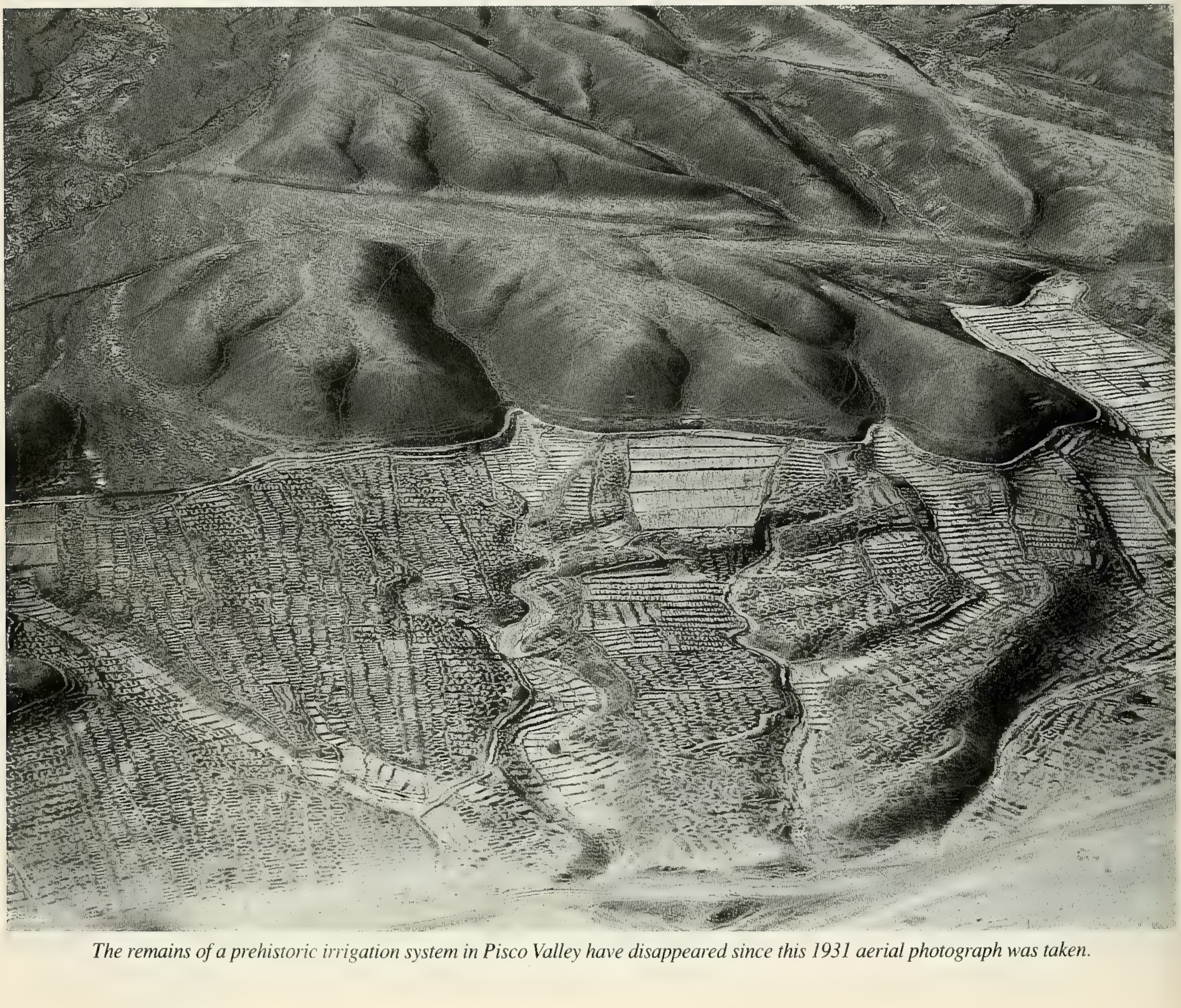
Recently a group of Peruvian colleagues and I have been conducting field research in the Chincha Valley, searching for evidence relating to the spondylus trade and looking closely at how the Chincha kingdom was incorporated into the empire of the Incas. This research has involved careful surveying on foot and in various kinds of vehicles. It has also involved three seasons of intensive excavation at several sites, including La Centinela, which served as the capital of the Chincha kingdom.

But our work has also involved the study of several sets of aerial photographs, including those taken by Bridges and the Shippee-Johnson team, and we continue to refer to their photographs. The excavations we are planning for the coming season at the site of Tambo de Mora, for example, will focus on a sector of the site that is no longer visible on the cultivated surface. This area was already an empty field by the time Bridges took her pictures in 1989.

But a Shippee-Johnson photograph of the same sector reveals architectural remains of facilities perhaps used by merchants in the Chincha Valley. Unlike the monumental truncated pyramids that we think were used for religious purposes by the ruling authorities, the platforms and enclosures may well have provided the storage, sorting, packing, and record-keeping areas that would have been part of a trading facility. Compared with the small reed structures that probably housed the common residents and workers of the valley, these buildings would have been quite substantial. Given these clues from aerial photographs, we hope our excavations turn up spondylus shells or other items of the reported Chincha maritime trade.

We have learned that the site was bulldozed, probably in the 1950s, in the rush to clear agricultural land. Even if we find artifacts and can trace some building walls, the original positions of the buried materials have been disturbed, and our findings may not be reliable. Nevertheless, these photographic records from the air provide important evidence of the way things used to be.

Craig Morris, dean of science and curator of South American archeology at the American Museum of Natural History, has written about the Chincha Valley excavations in his book The Inka Empire and Its Andean Origins.



Robert Shippee and George R. Johnson; AMNH

The remains of a prehistoric irrigation system in Pisco Valley have disappeared since this 1931 aerial photograph was taken.

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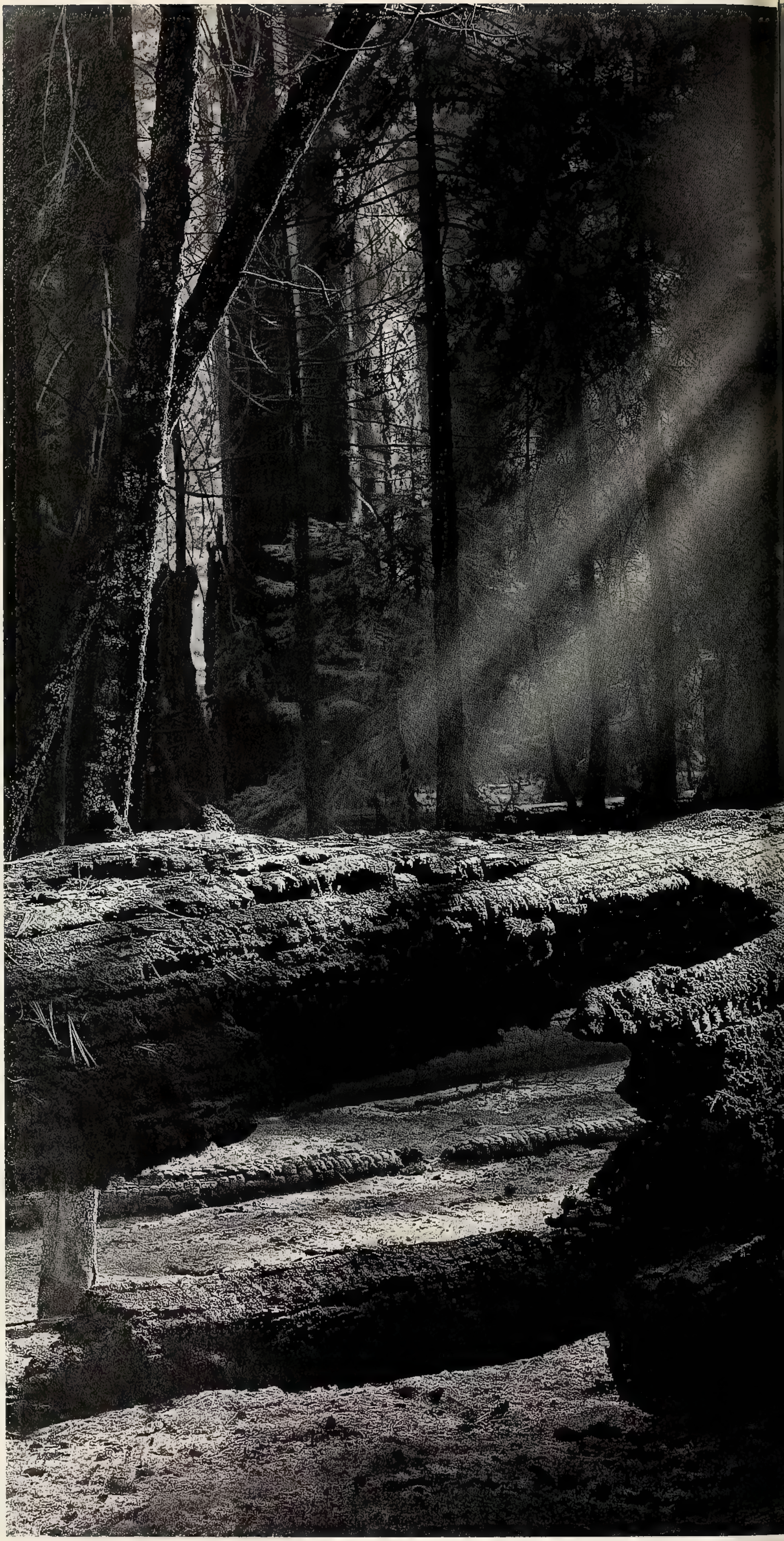
Still Life

At first glance, this stand of forest in Yosemite National Park looks pristine; sunbeams bathe a fallen tree in dappled light and illuminate a mist floating through the grove. But the mist is smoke, and the forest understory has just burned. The fire, which was still smoldering around John Sexton as he took this photograph, had reduced small trees, fallen branches, and needles to a thick layer of powdery gray ash, while sparing trees with a diameter of five inches or more. (The charred tree in the foreground had fallen long before the fire.) Such fires, ignited by lightning or by foresters in carefully managed burns, reduce the chances that a much hotter conflagration, fueled by accumulated wood and brush, will engulf the entire forest.

Fire can renew forests as well as destroy them. It can be seen as an extremely rapid form of decay, transforming organic material into its elemental components. Nitrogen is released as gas and goes up in smoke, but large amounts of other nutrients, such as phosphorus, potassium, and calcium, are returned to the soil. To take advantage of the newly fertilized soil and the open space cleared by the fire, many plants drop seeds that require the heat of a fire to initiate germination. Plants colonizing these rich ashbeds are more vigorous than those growing outside them. When Sexton returned to this spot several years later, new growth abounded.

Robert Anderson



Photograph
by John Sexton

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Eruption of Kilauea volcano on Hawaii

"When you're working on a volcano, your equipment and wits can't fail you."

—Dr. Michael Garcia

Earthquakes rock the black, rippled terrain. Fire fountains explode from the mountain's side. Iridescent orange lava, as hot as 2100° F, sweeps down the volcano's flanks in thin sheets and swift rivers. The air is filled with the roar of molten rock slamming against a crater wall. It rains pumice.

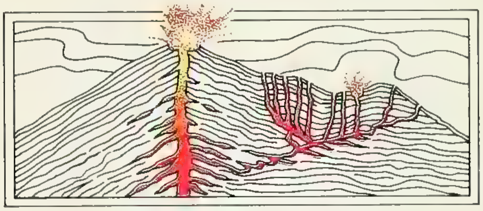
This is Kilauea, which ascends majestically from the floor of the Pacific and disgorges a continuous stream of lava that can fill a large stadium in less than a day.

Dr. Michael Garcia

Professor Michael Garcia has devoted his career to exploring the mysteries of volcanoes, particularly Kilauea,

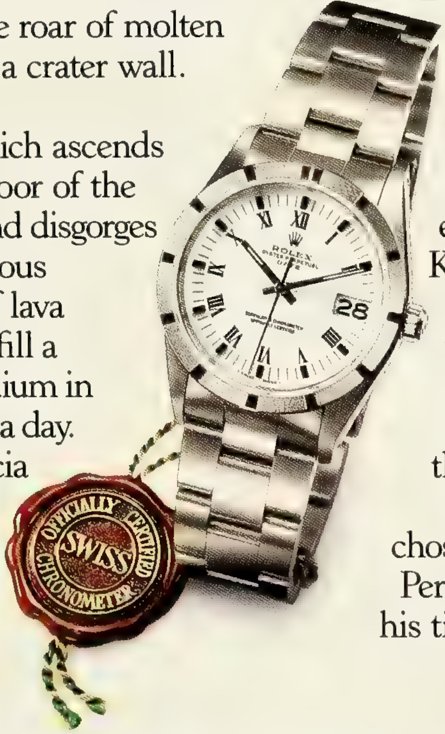
in the world. "It's the premier place to study how volcanoes work," he said.

Dr. Garcia has been gathering data on Kilauea since 1978. When he is not in the lab conducting chemical analyses of lava, Garcia is in the field, measuring intervals between fire-fountain pulses and plucking samples from lava rivers. He believes that a keener understanding of the volcano and its internal structure can help scientists better anticipate eruptions.



Magma conduits inside Kilauea

Working in such a hostile environment, Garcia must rely on his experience, instinct and equipment. "You have to respect Kilauea's might—especially when you feel it rumbling beneath your feet," he said. Demanding the highest standards from his instruments, Dr. Garcia insists that they be rugged and reliable. It's little wonder that he has chosen a Rolex Oyster Perpetual as his timepiece.



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